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Interstate Route 81 in the Pocono resort area, Susquehanna County, Pennsylvania.

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Application of Statistical Concepts to Accident Data

BY THE
BUREAU OF PUBLIC ROADS

Reported by ^{1,2} DONALD A. MORIN,
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Region 8, Portland, Oregon

In this article Morin has pointed out the necessity for applying statistical concepts to traffic accident data. Although procedures for determining the significance of accident data have already been developed little has been accomplished toward their application. Procedures are suggested by which the limited available accident data can be analyzed and erroneous conclusions avoided.

The importance of statistical analysis of data is illustrated by one State's failure to identify unstable accident rates. In this State's program, high priorities were assigned to some highway sections that had few accidents and low priorities were assigned to other sections that had numerous accidents. This and other examples of inaccurate interpretation of accident data illustrate the need for applying statistical concepts to accident data to determine the significance of accident rates. The author also discusses the normal chance variation in accident rates, the minimum accident rates that definitely exceed an established tolerable rate, and the percentage of accident reduction needed to establish the reliability of a road section improvement.

Introduction

THE CONCERN being expressed nationwide about the highway accident toll has generated a flood of magazine articles, promoted legislation, and encouraged discussion within technical circles as to what can and should be done. No pat answer or agreement on the solution has been reached. Some believe the solutions hinge on stricter enforcement of traffic regulations, others on more and better driver education, others on improved highways, and others on safer vehicles. Agreement seems to exist on one point, however, and that is the lack of adequate accident records to enable agencies to establish accurate conclusions on highway accidents. A method for obtaining adequate records is not proposed in this article, but methods are suggested by which better analyses of the limited available accident data can be made so that erroneous conclusions will not be made.

Conclusions

From the investigation of existing statistical procedures for interpreting available accident data several conclusions have been drawn.

- Although statistical procedures based on quality control concepts were developed and successfully applied to accident data a number of years ago, traffic and highway engineers have made only limited use of them to date.
- A procedure must be found to accelerate the use of existing statistical procedures over the pace of the past to permit concentration of manpower and resources in those areas that offer the best prospects for improvement.

- When applied, statistical controls have enabled engineers to make valid conclusions as to the effectiveness of safety improvement projects.

- Application of statistical procedures has also enabled engineers to determine the amount of variation inherent in accident rate data and thereby has minimized the possibility of erroneous conclusions.

Statistical Concepts Needed

Accidents are scarce events—a few accidents per million vehicle-miles of travel; the universe in which accidents occur is extremely large—many hundreds of millions of vehicle-miles. As a statistician might say, “We are dealing with a small sample of a large population.” In this situation, erroneous conclusions can easily be made unless the engineer uses well established statistical concepts to determine the significance of the accident data. Although most highway and traffic engineers are not specifically trained in statistics, they should be able to recognize when the services of statisticians are needed. Examples cited in the following paragraphs illustrate situations that required the application of statistical concepts to the analysis of accident data.

In one State, priorities on hazardous rural and urban highway sections were established by ranking the sections according to their annual accident rate, that is, the first priority was given to the section that had the highest annual accident rate. The fallacy of this procedure is evident from the assignment of priority 4 to a 1-mile section of a rural road on which only 3 accidents had occurred, none of which had caused personal injury or fatality, and the assignment of priority 47 to another 1-mile section of rural road on which 186 accidents had caused 89 personal injuries. In this same State, a 0.2-mile section of urban

road on which 66 accidents had caused 12 injuries was ranked 13th, and another 0.2-mile section of road on which 123 accidents had caused 70 injuries and 3 fatalities was ranked 190th. Of course, sections with few accidents had high accident rates and vice versa because of the wide variation in the number of vehicle-miles of travel on the sections. Road sections of equal length were not differentiated in terms of their respective vehicle-miles of travel.

In another State, the annual State highway accident report listed, by route, the accident rate for each control section. When submitted, each control section that had a rate of 10 or more accidents per million vehicle-miles of travel was underlined in red. Examination of the accident data for these sections showed that many of the sections having a rate of 10 or more were not significant nor worthy of closer scrutiny because only one or two accidents had occurred; the few accidents coupled with the low figures for vehicle-miles of travel produced high accident rates. Other seemingly significant sections on which the vehicle-miles of travel were large had not been singled out by the red underlining because the accident rates were slightly less than 10.

In another instance, highway and traffic engineers determined that the large number of accidents at a complicated intersection could be curtailed by the installation of overhead sign bridges, improved signals, and some limited approach widening. During the 3-month period after completion of the improvement project, the number of accidents had decreased by eight. A press release, *Intersection Made Safer*, stated that the city's “. . . most dangerous intersection . . . apparently has been tamed.” At the end of the following 8-month period, however, there had been only 5 fewer accidents, a 12-percent decrease that was far short of the 38-percent decrease needed to assure reliability. No press release or publicity was given to this.

The proper application of statistical concepts could make it possible to avoid pitfalls, like the ones cited, by determining the amount of normal chance variation that should be expected in accident rates, the minimum accident rate that definitely exceeds an established tolerable rate, and the percent of accident reduction needed to establish the reliability of a road improvement project.

An attempt is made in the rest of this article to summarize statistical concepts that have been developed and applied to this problem area. Although many of these applications were developed more than 10

¹ Presented at the 46th annual meeting of the Highway Research Board, Washington, D.C., January 1967.

² Mr. Morin is now Chief, Public Transportation Branch, Urban Planning Division, Office of Planning, Washington, D.C.

years ago, only limited use has been made of them.

Control Limits

The Office of Technical Services of the U.S. Department of Commerce in 1958 distributed a manual (1)³ that described a procedure for determining the amount of variation in the accident rate that could be expected from chance probability for any highway control section. The input required is the overall accident rate for the highway and the number of vehicle-miles of travel on the control sections. However, in 1966 S. K. Dietz discovered an error in the equations as originally presented in the Technical Service manual and HRB Bulletins 117 (2) and 341 (3). The validity was improved by omitting the correction term, 0.829/m. The authors of the original equations have concurred in Mr. Dietz's correction. By applying the corrected equations, both upper and lower control limits on the overall accident rate can be established for each control section.

$$\text{Upper control limit} = \lambda + 2.576\sqrt{\lambda/m} + \frac{1}{2m} \quad (1)$$

$$\text{Lower control limit} = \lambda - 2.576\sqrt{\lambda/m} - \frac{1}{2m} \quad (2)$$

Where,

λ = Overall accident rate for the highway.
 m = Vehicle-miles of travel on a control section.

Equations (1) and (2) provide expressions for the upper control limit that has a probability 1-P of being equalled or exceeded by chance. To define the upper control limit as one that has a probability 1-P of being exceeded, the equation would be,

$$\text{Upper control limit} = \lambda + 2.576\sqrt{\lambda/m} - \frac{1}{2m} \quad (3)$$

This is identical to equation (1) except that the sign of the $\frac{1}{2m}$ term is reversed.

To define the lower control limit as one that has a probability 1-P of being exceeded by a more negative number the equation would be,

$$\text{Lower control limit} = \lambda - 2.576\sqrt{\lambda/m} + \frac{1}{2m} \quad (4)$$

This is identical to equation (2) except that the sign of the $\frac{1}{2m}$ term is reversed.

Chance Variation

It is possible with the equations cited to compare the actual accident rate for each highway section with the control limits on the overall accident rate to determine whether the variation from the overall rate is more than could be attributed to chance. The coefficient of the second term in the equation, 2.576, assumes a 0.995 or $\frac{1}{2}$ of 1 percent probability level that either the upper or lower control limit could be exceeded by chance variation in the observed accident rate, or a 0.990 or 1-percent probability level

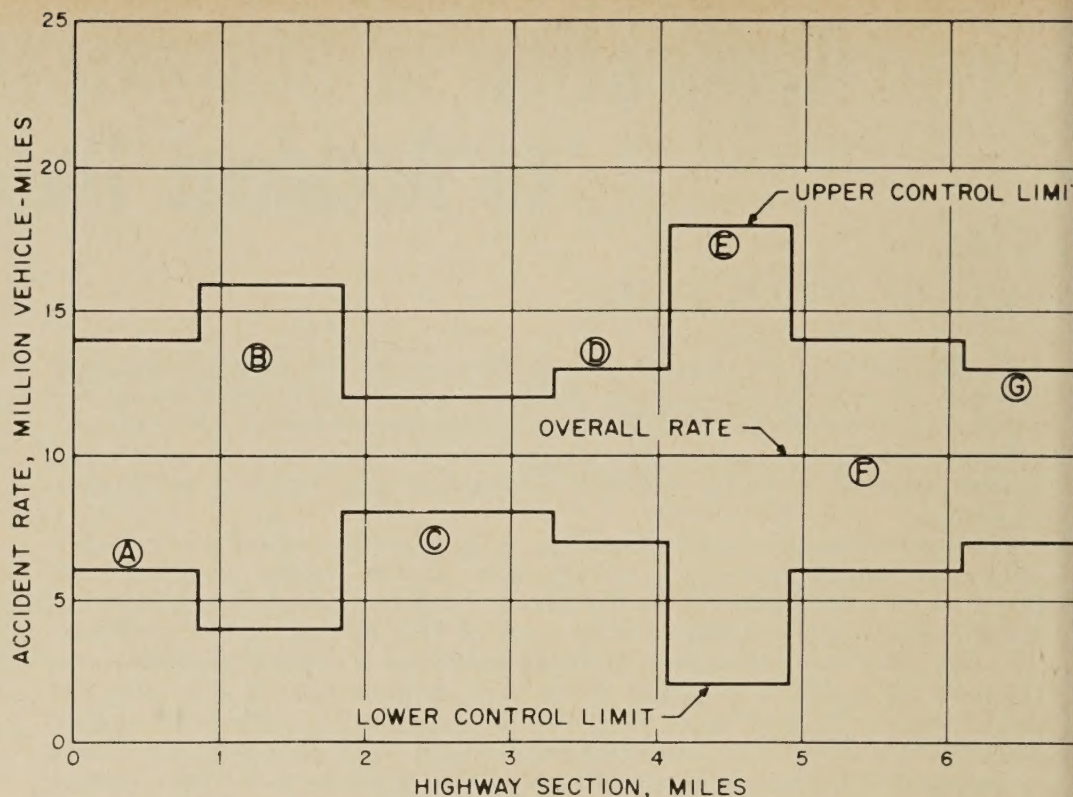


Figure 1.—Relation of actual accident rates to control limits on overall accident rates.

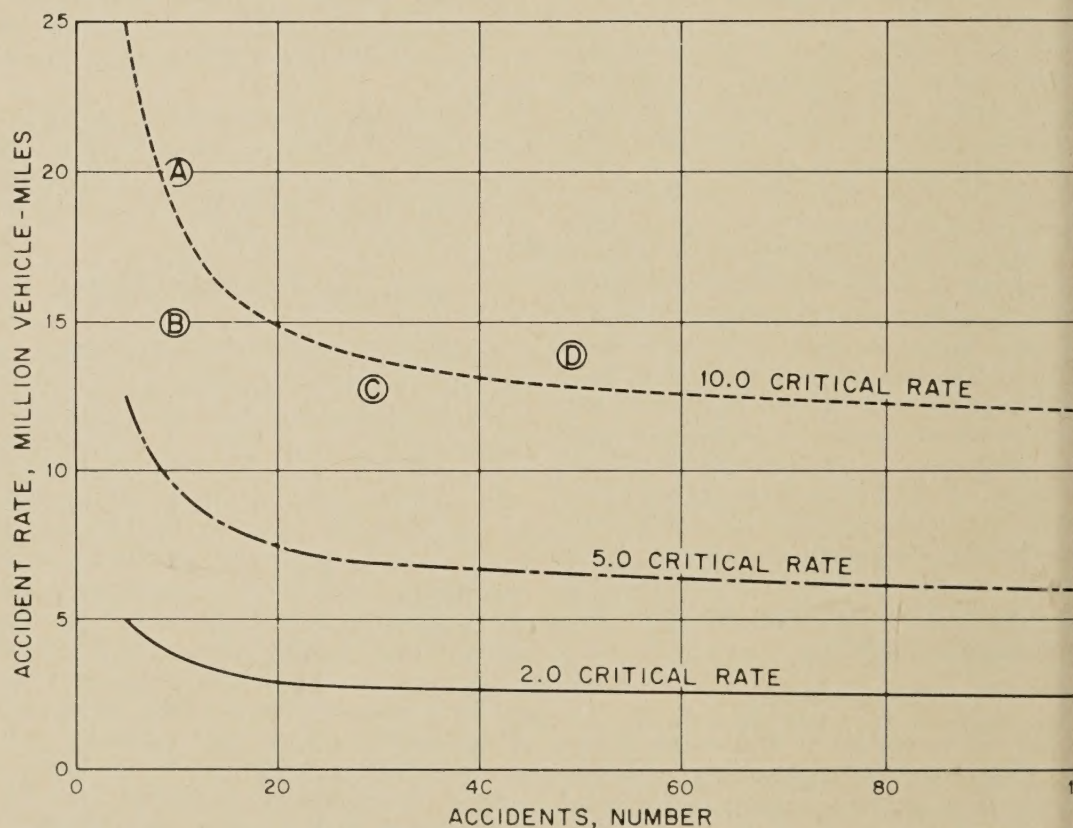


Figure 2.—Minimum accident rates statistically significantly higher than critical rates.

that both the upper and lower control limits could be exceeded by chance variation. For example, a value of 2.576 would mean that for 1 percent of the road sections the accident rate could be expected to fall beyond the control limits by chance even though there is nothing out of the ordinary about them, and that $\frac{1}{2}$ of 1 percent of the accident rates for the road sections could be expected to fall above the upper or below the lower control limit by chance even though there is nothing out of the ordinary about them.

Other coefficients that would change the probability of labeling a rate as out of the ordinary when it is in fact normal could be used: 1.960 for 5 percent false detection of both or 2½ percent of either; 1.645 for 10 percent false detection of both or 5 percent of either; 1.440 for 15 percent false detection of both or 7½ percent of either; 1.282 for 20 percent false detection of both or 10 percent of either.

A comparison of the actual accident rates to control limits on the overall accident rate

³ Italic numbers in parentheses indicate the references listed on p. 137.

n be made from figure 1. In the figure the observed accident rate at point E seems high. Because of the few vehicle-miles of travel on this section, the control limits differed widely from the overall rate. It should be concluded that the apparently high rate at point E was not worthy of investigation as it was within the range of variation that could be expected by chance. By comparison, the observed accident rate at point D does not appear to be very much higher than the overall rate and much lower than the rate at point E. It, because point D is outside the control limit for that section, its variation from the overall rate is more than could be attributed to chance. Accidents on this section of the road, therefore, warrant analysis. The accident rate indicated by point C should also be investigated, as something other than chance variation caused the accident rate to be so much lower than the overall rate. Investigation of the causes of this low rate might provide a means for attaining similar low rates on other road sections.

Rudy (3), in 1962 described the application of the Connecticut of the procedure for determining the amount of variation in the accident rate that could be expected from chance probability. The Montana State Highway Commission recently programed this procedure for their IBM 1620 computer and successfully ran their 1965 accident data. The program printed out the upper and lower control limits and the observed accident rate for each highway control section. The results were indicated in the 1965 Annual Accident Report by an asterisk alongside the computed accident rate for sections where these rates were outside the control limits. Because these variations from the overall rate did not occur by chance, the next logical step is to find the reasons for the abnormally high and low accident rates.

Under consideration is a procedure to assemble in one report all possible data concerning time and exact location of accidents, accident type, weather conditions, roadway alignment and cross section details, sight distance, and so on for those road sections where accident rates seem to be out of control. A team consisting of a traffic engineer, design engineer, maintenance engineer, and law enforcement officer would study the assembled data and physically look at the highway sections to determine the reason for the abnormal accident rates.

Critical Rate Analysis

A somewhat simpler application of statistical analyses to accident rate data, using the same basic concepts, is being used in Idaho. The procedure requires that the highway authority establish the critical accident rate, that is, the highest accident rate the authority agrees to tolerate. Then, for any established critical rate, a minimum accident rate can be determined for any number of accidents that is statistically significantly higher than the critical rate of accidents on a particular road section. Minimum accident rates that exceed the established

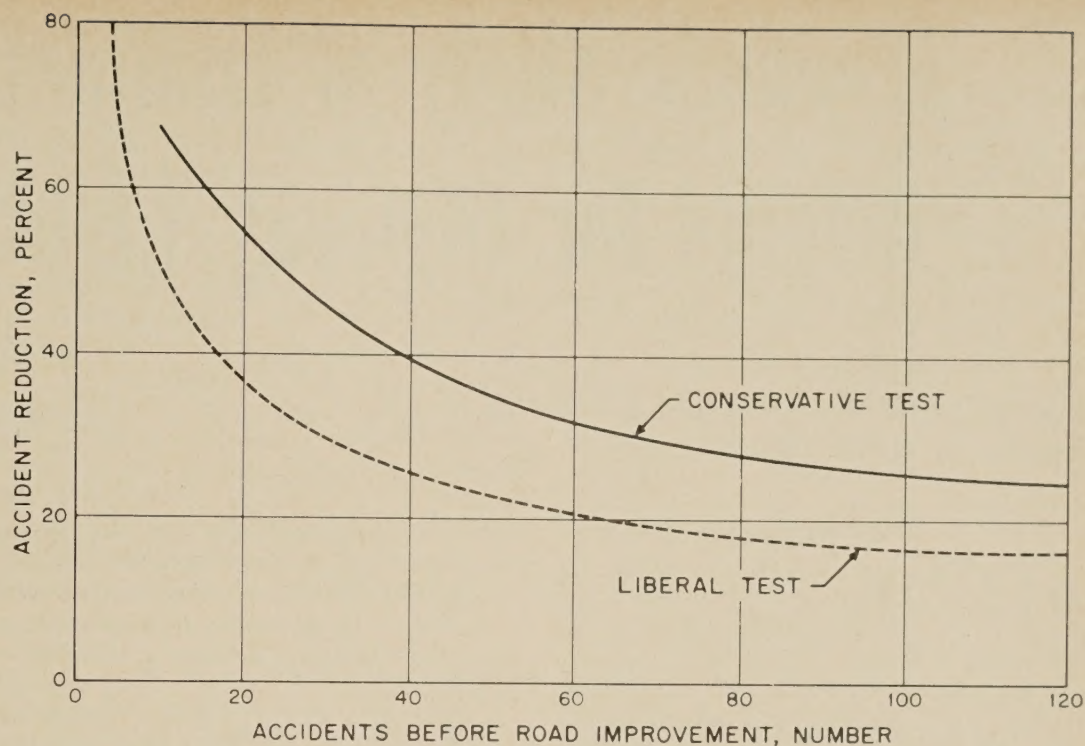


Figure 3.—Curves for use in determining statistical significance of reduction in number of accidents.

critical rates are illustrated in table 1 and figure 2.

In figure 2, the accident rates at points A through D and the established critical rate of 10 accidents per million vehicle-miles of travel indicate that the rate of 15 based on 10 accidents—point B—and 13 based on 30 accidents—point C—are not statistically higher than the critical rate of 10. The accident rates shown by points A and D, however, should be attributed to something other than chance variation; the rates of 20 based on 10 accidents—point A—and 14 based on 50 accidents—point D—are statistically significantly higher than the critical rate of 10 accidents per million vehicle-miles. Although the Idaho procedure provides a quick method for identifying road sections that have rates significantly higher than a predetermined critical or tolerable rate, it does not pinpoint road sections that have significantly low accident rates.

Effectiveness of Improvement Projects

In 1959 Dr. R. M. Michaels published a procedure for determining the statistical significance of the percentage of reduction in the number of accidents on a road section after improvement as compared to the number before improvement (4). The Poisson distribution was considered an appropriate approximation of the accident probability for the liberal test. The chi-square test was used to determine whether there was a significant difference between the before and after samples for the conservative test. One of the main advantages of this procedure is that the engineer can test for significance knowing only the number of accidents before the road improvement and the percentage of accident reduction after improvement of the road section. The test involves spotting the percentage of reduction on a graph, as shown in

Table 1.—Minimum accident rate statistically significantly larger than critical accident rate (probability level=0.95)

Critical accident rate per million vehicle-miles is—	Minimum accident rate per million vehicle-miles when—					
	Actual number of accidents per road section is—					
	5	10	20	30	50	100
2.0.....	5.0	3.7	3.0	2.8	2.6	2.4
3.0.....	7.5	5.6	4.5	4.2	3.9	3.6
5.0.....	12.5	9.3	7.5	7.0	6.4	5.9
7.0.....	17.5	13.0	10.5	9.8	9.0	8.3
10.0.....	25.0	18.5	15.0	14.0	12.8	11.9

figure 3, to determine the significance of the reduction. If the point falls below the conservative line, for example, the reduction is not significant by the conservative test.

The failure of engineers to apply the statistical procedures can lead to false conclusions about highway improvement. An engineer in a recent article (5) reported that no definite conclusions could be drawn from a safety experiment because data were too limited and not statistically significant. However, application of Dr. Michael's procedure showed that the percentage of reduction in accidents for the safety experiment was statistically significant by the conservative test. Another article (6) reported the success of a safety project; but statistical analysis of the percentage of reduction of accidents showed that the accidents had not been reduced significantly.

REFERENCES

- (1) *Manual for the Application of Statistical Techniques for Use in Accident Control*, by Jack W. Dunlap, Jesse Orlansky, and Herbert H. Jacobs, U.S. Department of Commerce,

(continued on p. 150)

Economic Study of Luminaire Mounting Heights for Highway Lighting Systems

BY THE OFFICE OF
ENGINEERING AND OPERATIONS
BUREAU OF PUBLIC ROADS

Reported by ¹ JAMES A. THOMPSON, Chief,
Lighting and Traffic Control Branch,
and BENDER I. FANSLER, Electrical Engineer,
Highway Standards and Design Division

Introduction

A WISER expenditure of public funds for highway lighting in relation to design should be possible from the information presented in this article. Details of an economic and engineering study of lighting designs for different mounting heights of luminaires for use on controlled-access highways and how the mounting heights affect lighting costs are presented. The method developed for evaluating different lighting designs should be useful in the design of more economical highway lighting systems. Although not a prime factor of the research study reported here, lighting system design can affect the esthetic properties of a highway and adequate lighting may increase safety on highways at night. Neither the degree of safety provided by night lighting nor the possible hazard of lighting poles along a highway has been formally studied, but the fewest possible poles per mile is a logical design consideration in relation to highway safety.

One of the factors sparking the study reported here is the increase in attention being given lighting of controlled-access highways in urban areas. As traffic volumes and operating speeds of vehicles have increased, a general public awareness of the need for and a demand for highway lighting has developed. Although several highway agencies have extensive lighting programs, many have limited programs or none at all. Despite the fact that each year highway engineers are considering the installation of more lighting systems, resistance to their cost plagues decision makers.

Although an economic study generally is a basic requisite for an engineering project, highway agencies heretofore have made little use of economic studies when designing highway lighting systems. The information and techniques discussed in this article should be helpful for evaluating proposed lighting projects. It is believed the evaluation methods discussed here emphasize the benefits to be derived from use of economic studies in relation to design. Methods for evaluating some of the cost differences of alternative designs are given, and other information is given on factors that may contribute to the design choice—factors that are impracticable to

An economic study is a valuable prerequisite for an engineering project. The authors of the study reported in this article believe that an economic evaluation of the different highway lighting systems would prove helpful to highway engineers in designing new systems. Details of an economic and engineering study of lighting designs for different mounting heights of luminaires for use on controlled-access highways and how the mounting heights affect lighting costs are presented here. Also, formulas are given for making evaluations for the different mounting heights of luminaires.

From the research it was concluded that an economic study, such as that reported in this article, would provide more economical and effective lighting system designs and ultimately contribute to improved highway safety and esthetics. Based on the study reported here, the previously accepted standard, 30-foot mounting heights for luminaires, may be considered undesirable; the authors believe that highway lighting systems designed to use luminaires mounted at heights of 40 to 50 feet would be preferable in terms of economy, effectiveness, safety, esthetics, and flexibility for future modification.

evaluate monetarily, such as esthetics and safety. An economic study should support planning and decision making so that more efficient and economical highway lighting installations can be provided—systems that will contribute to the safety and comfort of the road-user.

The authors caution that the cost information presented in this article represents relative values used only for examples in the economic evaluation procedures. The costs cited should not be used for project justification nor for budget preparations.

Conclusions and Findings

Application of the information and techniques for evaluating highway lighting system designs given in this article should be helpful to highway engineers responsible for designing new systems, according to the conclusions made by the authors. The evaluation of present design techniques by the cost-effectiveness procedure discussed in this article is a basis that can be used for evaluating different designs. Use of this economic evaluation during planning of a lighting system could assure a wiser expenditure of public funds for more effective and esthetic lighting systems. These improved lighting systems could also improve safety conditions on the highways. Specific findings and related conclusions based on the research are given in the following statements.

On the basis of the research reported here, the previously accepted standard of 30-foot mounting heights for luminaires may be considered undesirable for divided highways.

Highway lighting systems designed to use luminaires mounted at heights of 40 to 50 feet would be more economical and effective than the designs for luminaires mounted at 30 feet. Use of the higher mounting heights in lighting system designs generally would provide safer and more esthetic lighting. The designs using the higher mounting heights are more flexible and can be readily modified to use new lamp and luminaire improvements. Recent trends in lamp development are toward increased lamp efficiency and larger lumen output.

The uniformity of illumination should be studied and analyzed because the maximum to minimum ratio of illumination uniformity seems to be a more logical basis for comparison of the lighting system's effectiveness than the average to minimum ratio currently in use.

The authors also have concluded that continuous fluorescent bridge rail lighting, mounted at a low height, is not a wise investment of public funds because installation cost is high for such a system, questions abound as to the effectiveness of bridge rail lighting, and maintenance difficulties are many.

Definite conclusions regarding tower lighting for interchange areas generally cannot be based on the evaluation of a single interchange. Design engineers should make a cost-effectiveness study for each individual interchange for which a lighting system is being planned because many geometric designs are available for the different requirements at each interchange.

¹ Presented at the 46th annual meeting of the Highway Research Board, Washington, D.C., Jan. 1967.

The annual cost of towerlighting or floodlighting may be approximately the same as the annual cost of a design for 30-foot mounting heights. The initial cost for each of the three tower designs evaluated in the research reported here was less than the initial cost for a 30-foot mounting height design.

Study Methods

In the research reported here, only one section of a highway was used to develop an evaluation method for determining the most suitable and economical highway lighting system. Geometric and lighting design criteria were based on current design standards and principles, and they were selected so that the principal variable would be the mounted height of the luminaire. The cost and designs for the most commonly used mounting height of 30 feet were compared to the same factors for mounting heights of luminaires at 40, 45, and 50 feet; on bridge rail lighting at a height of 3½ feet; and floodlights (a type of luminaire) mounted at a height of 100 feet in towers or on poles. Costs were computed for the following listed designs: (1) 250-watt lamps on 2-lane roadways; (2) 400-watt lamps on 2-, 3-, and 4-lane roadways; (3) 700-watt lamps on 3- and 4-lane roadways; (4) 1,000-watt lamps on 4-lane roadways; (5) bridge rail lighting; and (6) interchange area floodlighting.

Only designs for divided, controlled-access highways were considered. Comparable designs for lighting systems were compared for only one direction of a roadway for 2-, 3-, and 4-lane pavements. All lanes were 12 feet wide and the right shoulders were 10 feet wide. The luminaires were located over the right edge of the traveled way. Bridge rail lighting systems were evaluated with the roadway lighting systems but lighting for interchange areas was evaluated separately.

A design level of average initial horizontal illumination of 1.0 footcandle and an average minimum uniformity ratio that did not exceed 3 to 1 was used for all overhead lighting system evaluations. A few design adjustments were made to obtain an acceptable lighting uniformity ratio, which caused some deviation from the average 1.0 footcandle of initial horizontal illumination. The minimum acceptable level of average initial illumination was established as 0.8 footcandle.

All overhead lighting designs considered were based on one manufacturer's design charts for use of clear mercury lamps. At the higher mounting heights, increased lamp wattages were required to maintain the 1.0 footcandle initial illumination at a fairly constant level. Therefore, 700-watt (34,600-lumen) and 1,000-watt (53,000-lumen) mercury lamps were used when design requirements exceeded the capacity of the 400-watt (19,500-lumen) lamp. The 250-watt (10,500-lumen) mercury lamps were used only for designs for 30-foot mounting heights. For bridge rail lighting design, 42-inch, 33-watt (2,190 lumens or 300 milliamperes) fluorescent lamps in 30-foot luminaires were studied.

For bridge rail lighting, in which light poles would be eliminated, fluorescent lights are mounted in a continuous line adjacent to or in lieu of a bridge railing. Although the concept and design for low-mounted lighting is different from overhead lighting, comparisons were made for installations that were judged to be comparable. Horizontal footcandle illumination, glare, and uniformity of illumination, which are the most common performance criteria used in designing a lighting system, did not seem to be a logical basis for comparing the low- and overhead-mounted lights. Other researchers have noted that a different method should be used to compute the average value of roadway illumination than is used to evaluate overhead lighting. Although the designs are different, for the purposes of this study the low-mounted lighting designs were considered to be similar to the overhead lighting system designs.

Other design criteria assumed to be constant for the lighting systems so that the principal variable would be the mounting height were: (1) Galvanized steel poles, anchor base, and concrete foundations; (2) 12-foot brackets, luminaire located over the edge of traveled way; (3) underground wiring system using

cable-conduit; (4) multiple system circuitry; (5) power delivered at secondary voltage, no load center considered; (6) median wide enough so that lighting from opposite lanes would not be a factor; (7) comparable characteristics of pavement reflection so adjustments would not be required in computing average initial horizontal illumination; (8) time controls equivalent for all systems; (9) medium, semicutoff luminaires of IES types II and III; and (10) ballast in luminaires.

Interchange floodlighting systems may be designed so that mounting heights of the luminaires range from 80 to 150 feet. Each interchange should be evaluated separately to determine the mounting heights that will best fit the geometric features. A floodlighting system differs somewhat in concept from the 30- to 50-foot mounting height designs for roadway lighting systems. Footcandles computed for controlled lens lighting may be similar to footcandles computed for floodlighting but roadway brightness measured by footlamberts may be different. The floodlighting design generally used was considered to be comparable to the overhead system designs used in the study reported in this article. A sketch of the interchange area used in the study discussed herein is shown in figure 1.

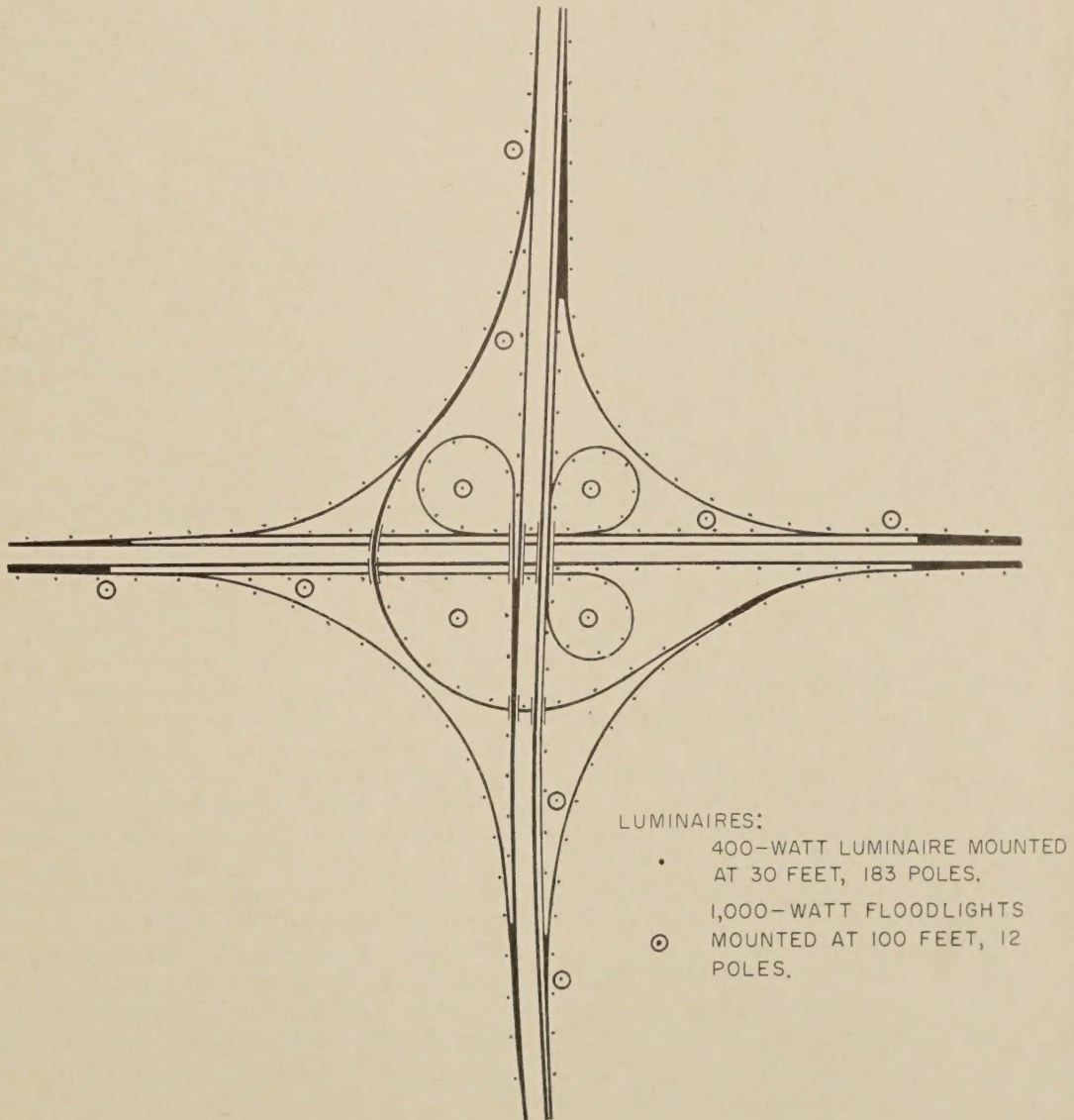


Figure 1.—Interchange layout of lighting poles for 30-foot and 100-foot mounting heights of luminaires.

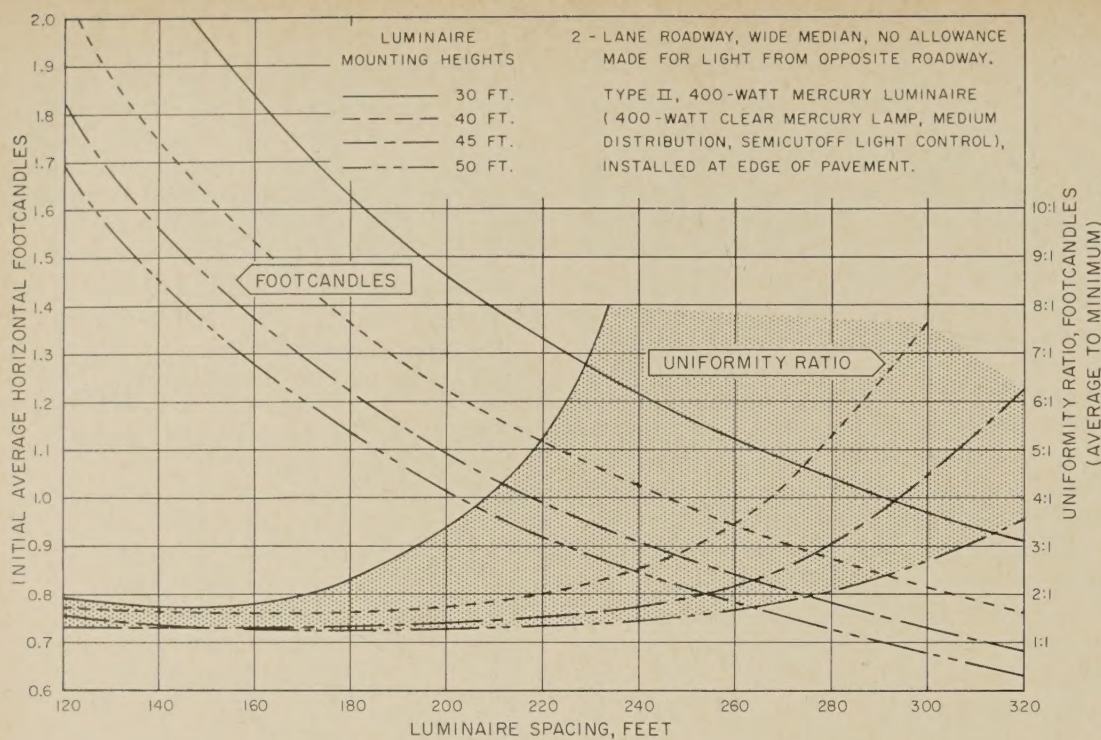


Figure 2.—Initial average footcandles and lighting uniformity ratio for different mounting heights and luminaire spacing for 2-lane roadway.

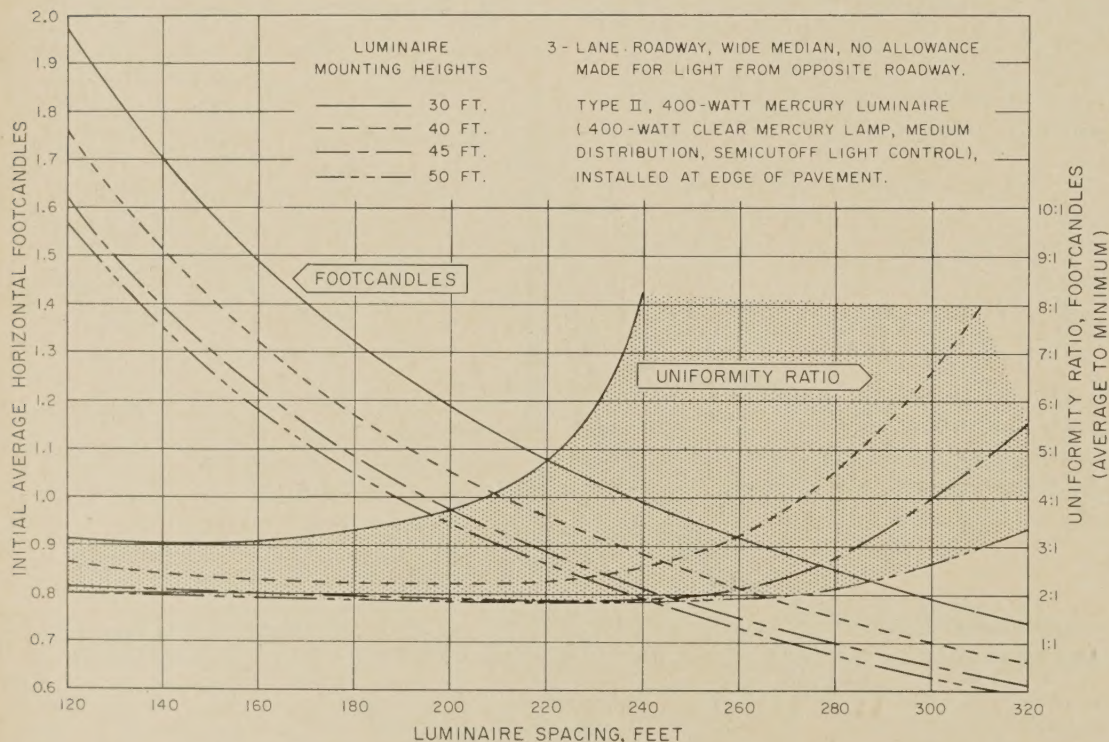


Figure 3.—Initial average footcandles and lighting uniformity ratio for different mounting heights and luminaire spacing for 3-lane roadway.

The area was 6.75 miles of separate roadways. Floodlighting designs using 400-watt and 1,000-watt lamps were evaluated. Also an industrial type, symmetrical distribution luminaire design, in which 1,000-watt lamps are used, also was evaluated.

Cost Data Conditions and Estimates

The cost data in this article are based on information considered typical of national averages. These data are given as a basis for determining relative initial, operating, and maintenance costs for lighting systems in which the luminaires are installed at different mounting heights. These cost data should

not be used as a guide for estimating the cost of specific highway lighting projects because material, delivery charges, electric energy, labor rates, and other costs may vary at different geographical locations. Initial costs for individual items were combined to obtain a total initial cost per mile, which was statistically converted and is restated as an equivalent annual cost. Luminaire maintenance and lamp replacement costs also were computed and are stated as equivalent annual costs. The estimated costs of luminaire cleaning and lamp replacement were based on maintenance being performed by owners and users. Repairs necessary because of

Table 1.—Luminaire cleaning and lamp replacement costs

Luminaires			Lamps		
Mounting height	Cleaning schedule	Estimated cost of cleaning one	Wattage	Group replacement schedule	Estimated cost
Feet			Watts	Years	
3 1/2	Semiannually	\$2.00	33	2	\$2.
30	Semiannually	1.50	250 400	4	{ 8.0 8.0
40	Annually	1.50	400 700 1,000	4	{ 8.0 14.0 16.0
45	Annually	1.75	400 700 1,000	4	{ 8.0 14.0 16.0
50	Annually	2.00	400 700 1,000	4	{ 8.0 14.0 16.0
100	Biannually	3.00	400 1,000	4	{ 8.0 16.0

¹ Cleaning costs were based on current maintenance practice but more frequent cleaning obviously would be required to keep maintained illumination from this type of luminaire comparable to overhead lighting.

vandalism, pole knockdowns, and other miscellaneous factors were not considered in the evaluation.

The basic formula used to determine the equivalent annual capital cost, EAC , of a lighting system for a life expectancy of n years from an initial cost, C , at an interest rate of i percent is,

$$EAC = C \frac{i(1+i)^n}{(1+i)^n - 1} \quad (1)$$

Where,

n = 20 years life expectancy for lighting systems evaluated in study reported here.

i = 6 percent interest.

$\frac{i(1+i)^n}{(1+i)^n - 1}$ = Uniform series capital recovery factor, crf , at an interest rate of 6 percent and life expectancy of 20 years.

Therefore, for the computations discussed in this article,

$$EAC = C \cdot crf$$

The basic formula used to determine the present worth, PW , of a single investment, I , n years in the future at an interest rate of i percent is,

$$PW \text{ of } I = I \frac{1}{(1+i)^n} \quad (2)$$

Where,

$\frac{1}{(1+i)^n}$ = Single payment present worth factor, pwf .

The formula for determining present worth therefore becomes,

$$PW \text{ of } I = I \cdot pwf \quad (2a)$$

Normally, the lighting system constructed and operated by a government agency is financed from road-user taxes in a method similar to that used to finance roadway construction. The road-user taxpayer is allowed to keep it, could invest this tax money and earn a return. This cost-

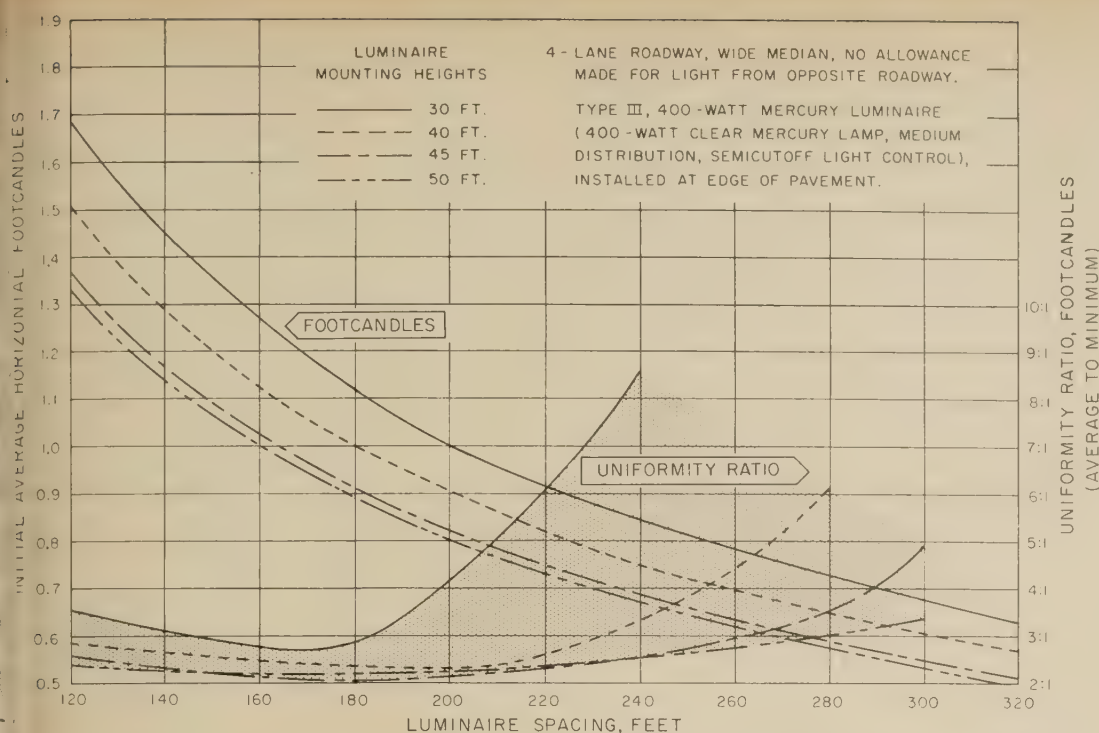


Figure 4.—Initial average footcandles and lighting uniformity ratio for different mounting heights and luminaire spacing for 4-lane roadway.

Table 2.—Material and installation cost estimates for different luminaire mounting heights

Item	Luminaire mounting heights, feet—					
	3½	30	40	45	50	100
Luminaire and ballast:						
6-foot fluorescent.....	126					
250-w. mercury.....		92				
400-w. mercury.....		92	92	92	92	
700-w. mercury.....			144	144	144	
1,000-w. mercury.....			158	158	158	
400-w. mercury floodlight.....						125
1,000-w. floodlight.....						200
Lamps						
42-inch, T6 fluorescent.....	2					
250 w. mercury.....		8				
400-w. mercury.....		8	8	8	8	8
700-w. mercury.....			14	14	14	
1,000-w. mercury.....			16	16	16	16
Poles.....		200	250	275	325	2,000
Installation per luminaire ¹	40	350	400	425	450	750

¹ Includes cost for foundation, bolts, wiring, conduit, trenching, and all miscellaneous labor and materials.

² Per pole.

vestment-opportunity cost should be the minimum interest figure used for determinations of the equivalent annual cost for an initial investment in a highway lighting system. A minimum interest rate should be established that is based on rates of investment opportunities foregone by the taxpayers, but it should be tempered by the element of risk for the 20-year predicted life of the lighting system.

The minimum attractive interest rate should include a safety factor as recognition that even the best engineering estimates are subject to error. Therefore, an interest rate of 6 percent has been used for present worth and capital recovery computations. A 20-year equipment life and no salvage value was used because it was estimated that 20 years is the economic life of most of the system components. It was assumed that the lighting system would be owned by a government agency, which would eliminate tax and insurance costs from the evaluation.

Procedures for maintaining a highway lighting system should always be considered in the design of the system. However, because of the infinite variations in mounting heights and the uncertainty in determining a maintenance factor for bridge rail lighting, and to a lesser degree for the 100-foot mounting heights, maintenance factors such as lumen maintenance and dirt were not included in the evaluation of the highway designs in the study reported here. The omission of maintenance factors permitted logical comparisons of the designs.

Luminaire cleaning schedules vary; they depend on the mounting height, highway geometries, traffic volumes, and location. The luminaire and lamp maintenance cost data shown in the study reported in this article are shown in table 1. Material and installation cost estimates are shown in table 2. Cost

summary data are given in tables 3 through 6. The total kilowatt electric load per luminaire was based on lamp wattage, plus ballast loss wattage, plus a line loss of 5 percent. The lighting operation was estimated at 4,000 hours per year and the assumed current cost at \$0.015 per kilowatt-hour.

Safety

Few subjects have received so much attention and so little opposition as highway safety. The three major variables of highway safety are the driver, the vehicle, and the highway. Each variable considered separately is complex and indefinite, but combined, the variables present a mass of intangibles so nebulous and replete with insupportable opinions that it is impracticable to establish costs for accidents.

Information in some recent study reports indicates that lighting contributed to safer highway operations during darkness. But, formal research has not been reported that evaluates the degree of safety provided at night by highway lighting. Neither has the degree of hazard created by lighting poles along the highways been established for either day or night. Regardless of the lack of conclusive evidence, it seems logical, when considering highway safety, to favor a lighting system designed for the fewest possible number of poles per mile. It also seems logical to assume that operation in an interchange area would be safer if the number of lighting poles were reduced and located farther from the edge of the travelway. Towerlighting in lieu of roadside poles would provide such a situation. In addition, lighting the entire interchange area rather than just the roadways might improve safety.

The ability to see an object is reduced by glare in the field of view. The glare may be reduced by increasing the luminaire mounting

height when the candlepower values remain constant. If glare is reduced, it follows that the result will be better visibility and improved safety. The authors, supported by observations, believe that an improvement in the uniformity of illumination, even when a slight reduction in level of illumination is necessary, would provide better highway lighting. This is one of the advantages to be gained from higher mounting heights and should be evaluated as a safety improvement.

Bridge rail lighting cannot be evaluated in the same manner as general highway lighting; poles on bridges are not considered hazards because they are located on top or behind the bridge parapet. Because the mounting height of the bridge rail lighting is approximately on a level with the driver's eyes, any resultant glare would be a negative value in highway safety consideration. Also, because of the lack of light directed to the top and rear of the vehicles, a negative safety value may be introduced in the evaluation of bridge rail lighting. But driving conditions during fog or other bad weather may be improved by bridge rail lighting because roadway delineation is improved.

Esthetics

All other design features considered equal, the height of the lighting pole can either enhance or detract from the esthetic quality of the highway. On narrow roadways, lighting from 30-foot mounting heights of luminaires is satisfactory. On wide roadways designed with a wide median or more than one median, a 30-foot mounting height may require four or more rows of poles. The result could be an unsightly forest of poles. A higher mounting height, combined when necessary either with 700-watt or 1,000-watt luminaires, sometimes may permit a reduction

Table 3.—Cost summary for 2-lane roadway

	Luminaire mounting heights, feet—					
	30	30	40	45	45	50
DESIGN DATA, 2-LANE ROADWAY						
Luminaire:	II	II	II	II	II	II
Type.....feet.....	190	195	250	280	220	210
Spacing.....feet.....	28	27	21	19	24	25
Per mile.....number.....						
Lamp.....watts.....	250	400	400	400	400	400
Illumination:						
Avg. to minimum.....ratio.....	3 to 1	3 to 1	3 to 1	3 to 1	1.6 to 1	1.4 to 1
Avg. initial horizontal.....footcandles.....	0.83	1.50	1.00	0.79	1.00	1.00
Minimum.....do.....	0.29	0.50	0.33	0.27	0.64	0.72
COST DATA, 2-LANE ROADWAY						
Initial cost.....per mile.....	\$18,200	\$17,550	\$15,750	\$15,200	\$19,200	\$21,875
Annual cost:						
Equivalent capital.....do.....	1,587	1,530	1,373	1,325	1,674	1,907
Equivalent maintenance.....do.....	129	124	65	64	81	90
Power.....do.....	512	770	599	542	684	713
TOTAL.....do.....	2,228	2,424	2,037	1,931	2,439	2,710

Table 4.—Cost summary for 3-lane roadway

	Luminaire mounting heights, feet—							
	30	40	40	40	45	45	50	50
DESIGN DATA, 3-LANE ROADWAY								
Luminaire:	II	II	II	II	II	II	II	II
Type.....feet.....	150	255	220	225	220	265	190	290
Spacing.....feet.....	35	21	24	24	24	20	28	18
Per mile.....number.....								
Lamp.....watts.....	400	400	400	700	400	700	400	700
Illumination:								
Avg. to minimum.....ratio.....	3 to 1	3 to 1	2.3 to 1	3 to 1	1.8 to 1	3 to 1	1.8 to 1	3 to 1
Avg. initial horizontal.....footcandles.....	1.60	0.83	0.96	1.29	0.90	1.02	1.00	0.85
Minimum.....do.....	0.53	0.27	0.42	0.44	0.50	0.33	0.55	0.28
COST DATA, 3-LANE ROADWAY								
Initial cost.....per mile.....	\$22,750	\$15,750	\$18,000	\$19,392	\$19,200	\$17,160	\$24,500	\$16,794
Annual cost:								
Equivalent capital.....do.....	1,983	1,373	1,569	1,691	1,674	1,496	2,136	1,464
Equivalent main-tenance.....do.....	161	65	75	104	81	91	101	87
Power.....do.....	998	599	684	1,174	684	978	798	880
TOTAL.....do.....	3,142	2,037	2,328	2,969	2,439	2,565	3,035	2,431

Table 5.—Cost summary for 4-lane roadway

	Luminaire mounting heights, feet—								
	30	40	40	40	45	45	50	50	50
DESIGN DATA, 4-LANE ROADWAY									
Luminaire:									
Type.....	III	III	II	III	II	III	III	II	III
Spacing.....feet.....	185	180	220	210	255	250	160	280	265
Per mile.....number.....	29	29	24	25	21	21	33	19	20
Lamp.....watts.....	400	400	700	1,000	700	1,000	400	700	1,000
Illumination:									
Average to minimum.....ratio.....	3 to 1	2.4 to 1	3 to 1	3 to 1	3 to 1	3 to 1	2.2 to 1	3 to 1	3 to 1
Average initial horizontal.....footcandles.....	1.09	1.00	1.13	1.80	0.91	1.42	1.00	0.80	1.28
Minimum.....do.....	0.36	0.43	0.36	0.60	0.30	0.47	0.47	0.27	0.43
COST DATA, 4-LANE ROADWAY									
Initial cost.....per mile.....	\$18,850	\$21,750	\$19,392	\$20,600	\$18,018	\$18,354	\$28,875	\$17,727	\$18,980
Annual cost:									
Equivalent capital.....do.....	1,643	1,896	1,691	1,796	1,571	1,600	2,517	1,545	1,655
Equivalent maintenance.....do.....	134	90	104	118	96	104	119	92	104
Power.....do.....	827	827	1,174	1,725	1,027	1,449	941	929	1,380
TOTAL.....do.....	2,604	2,813	2,969	3,639	2,694	3,153	3,577	2,566	3,139

in both the number of rows and number of poles and may improve the appearance of the highway at all times.

The taller poles are esthetically acceptable when the ratios of roadway widths to pole heights are considered. When the design norm is considered to be 24-foot, 2-lane, 2-way roadways (two, 12-foot lanes and two 10-foot shoulders) equipped with 30-foot poles, the ratio of roadway width to height of pole is 44 to 30, or approximately 1.5 to 1. Therefore, a 50-foot pole should be acceptable for roadway widths of 75 feet or more, 100-foot poles or towers should be acceptable for roadway widths of 150 feet or more. And in areas where the type of property development adjacent to the highway is higher than the lighting poles—such as industrial plants, high rise apartment buildings, and so on, where deep roadway cuts exist—the tall poles or lighting towers blend more readily with the local environment than the shorter poles. But, if the adjacent area has one-story dwellings and the roadway cuts are shallow, use of a shorter pole may be more desirable.

Towerlighting in wide interchange areas seems to be esthetically desirable when acceptable width to height ratios exist. Lighting at night of landscaped areas between ramps enhances the appearance of the interchange area. The spill of light off the highway, which may occur when the mounting heights are higher than the surrounding areas, could be either a positive or a negative factor in the design evaluation of highway lighting. The quality of the factor would depend on the adjacent property and the property owner. In a highly developed area where crime is a problem, spilled light could be an asset to owners of business and residential property. In relation to police protection, lighting is an asset in any area. Spilled light could be a negative factor and a source of complaint in private residential areas where crime is a problem. In apartment dwelling and business areas, lighting is normally furnished for walking and parking areas, so spilled light from the highway may be desirable.

Bridge rail lighting has been promoted as an esthetic improvement even though it may break the continuity of overhead lighting for the highway. The use of rail lighting rather than lighting poles on bridges seems to present a more pleasing appearance during the day. This factor would weigh more heavily in design of bridge lighting on a parkway or scenic highway. As in the evaluation of safety, a similar value cannot be given to the esthetic qualities of highway lighting, but for specific conditions, some weight should be given to choosing a lighting design that would fit or blend with the highway and adjacent property.

Results of Study

The safest and most esthetic overhead lighting system may be considered the one that provides adequate and effective illumination with the fewest number of poles. The number of poles per mile can be reduced by use of higher mounting heights combined, when necessary, with more wattage for luminaires and lamps. As poles are the most costly item of the lighting system, a system design that reduces the number of poles generally will offset the cost of taller poles, larger foundations, and larger luminaires. Lamps are a small part of the cost.

Three factors are of prime consideration in the effectiveness of any highway lighting system: the level of illumination, the uniformity of illumination, and the control of glare. The uniformity of illumination may be more important than the footcandle level of illumination. And, as the mounting height of lamps is increased, the apparent improvement in light distribution may be better than a comparison of average to minimum illuminating uniformity ratios would indicate. It seems doubtful that the ratio of maximum to minimum illumination factors should receive more consideration when alternatives are evaluated. Additional study to determine a more positive evaluation of light distribution related to uniformity in level of illumination is recommended by the authors. Results of such a study might show that the road-users ability to perform driving tasks may be improved more by better uniformity in level of illumination than by an increase in the footcandles of illumination.

Luminaires having cutoff vertical light distribution will help to reduce glare and may provide better visibility for the motorists than semicutoff luminaires. The least glare control is possible when noncutoff luminaires are used, and their use probably should not be considered for expressway lighting. When roadways are narrow, a high mounting height provides distribution of light on the opposite roadway. Because the position of the luminaire in relation to the traveled way is not as critical, many times it may be possible to save on the initial cost of a system by use of shorter bracket arms. When the 30-foot mounting heights are used, a pronounced light spot is present under or near each luminaire. The size and brightness contrast of these pools of light can be reduced considerably by use of higher mountings—less

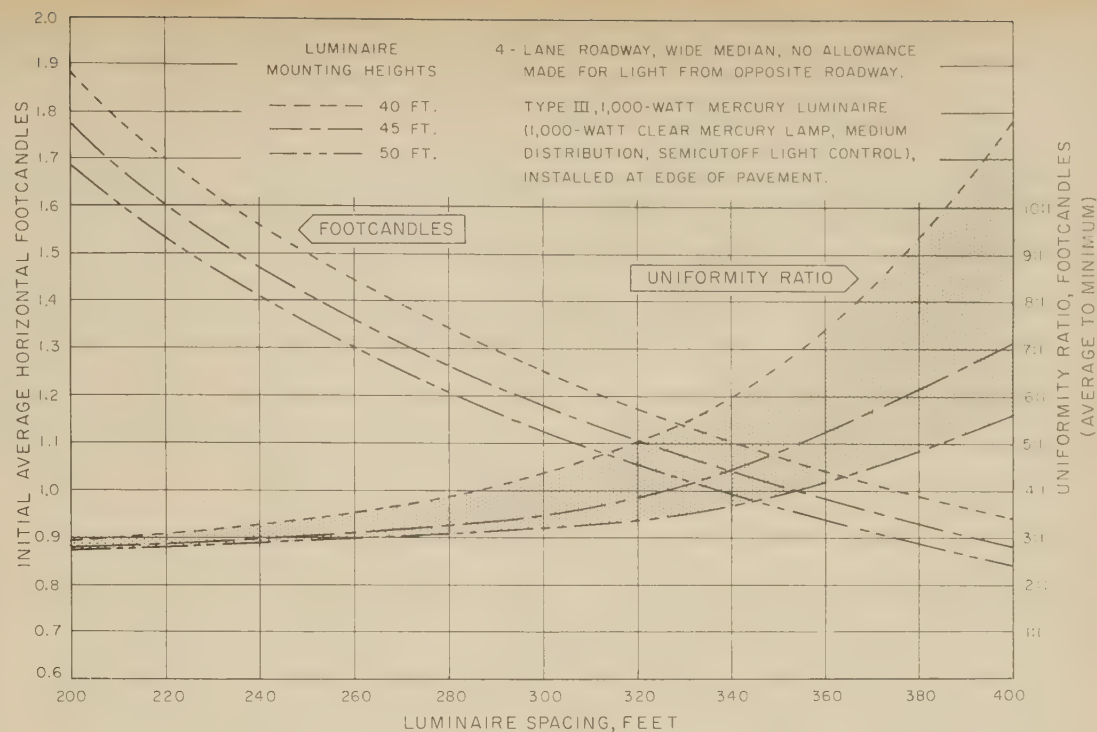


Figure 5.—Initial average footcandles and lighting uniformity ratio for different mounting heights and luminaire spacing for 4-lane roadway.

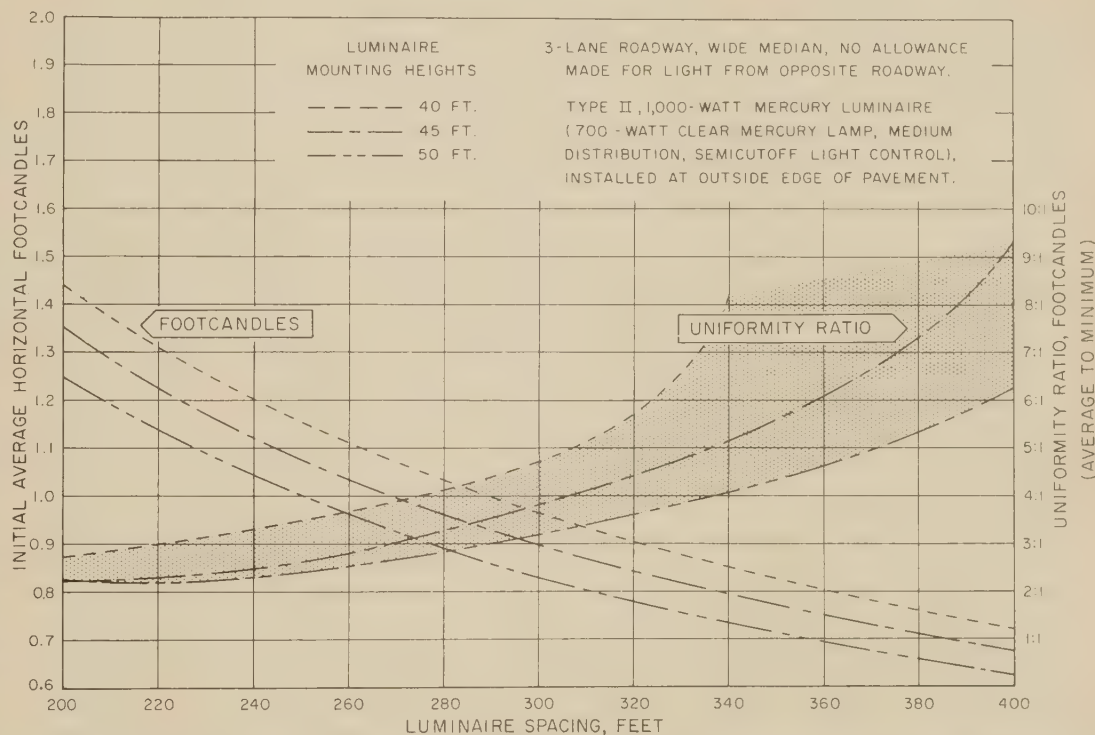


Figure 6.—Initial average footcandles and lighting uniformity ratio for different mounting heights and luminaire spacing for 3-lane roadway.

variation is present in pavement brightness and the frequency of eye adaptation is lessened because the driver is not traveling through a succession of intermittent bright spots.

According to results of a cost-effective analysis, a 30-foot mounting height for luminaires seldom should be used for lighting a divided, controlled-access highway. The curves in figures 2 through 7, which show the relation of luminaire spacing to lighting uniformity, illustrate that less change occurs in lighting uniformity in relation to an increase in luminaire spacing if the mounting height is increased. This relation also indicates that differences that may exist between calculated

and actual measured uniformity would be less as the mounting height is increased.

Data that can be obtained from curves shown in figures 2 through 7 can be an aid in the preliminary design of a lighting system. For example, figure 2 shows that for a 30-foot mounting height of luminaires on a 2-lane roadway, 1.5 initial average horizontal footcandles of illumination are required to obtain a 3 to 1 lighting uniformity ratio and 1.4 footcandles for a 4 to 1 uniformity ratio. But at the 40-foot mounting height of luminaires, 0.8 to 1.2 footcandles of initial average horizontal level of illumination can be obtained when uniformity ratios are about 8 to 1 or 1.7

Table 6.—Cost summary for interchange floodlighting ¹

	Luminaire mounting heights, feet—			
	30	100	100	100
DESIGN DATA, INTERCHANGE FLOODLIGHTING				
Light distribution.....type.....	II	Flood	Flood	V
Poles.....number.....	183	12	12	27
Luminaires.....number.....	183	492	204	108
Per pole.....number.....	1	41	17	4
Lamp.....watts.....	400	400	1,000	1,000
Illumination:				
Average to minimum.....ratio.....	3 to 1	Approx. 3 to 1	Approx. 3 to 1	Approx. 2 to 1
Average initial horizontal.....footcandles.....	1.5	Approx. 1.0	Approx. 1.0	Approx. 1.0
COST DATA, INTERCHANGE FLOODLIGHTING				
Initial cost.....	\$118,950	\$98,436	\$77,064	\$101,628
Annual cost:				
Equivalent capital.....	10,370	8,582	6,718	8,860
Equivalent maintenance.....	844	2,268	1,269	672
Power.....	5,216	14,022	14,076	7,452
TOTAL.....	16,430	24,872	22,063	16,984

¹ Through roadways are two, 12-foot lanes and all ramps have 1 lane except the directional ramp, which has 2 lanes.

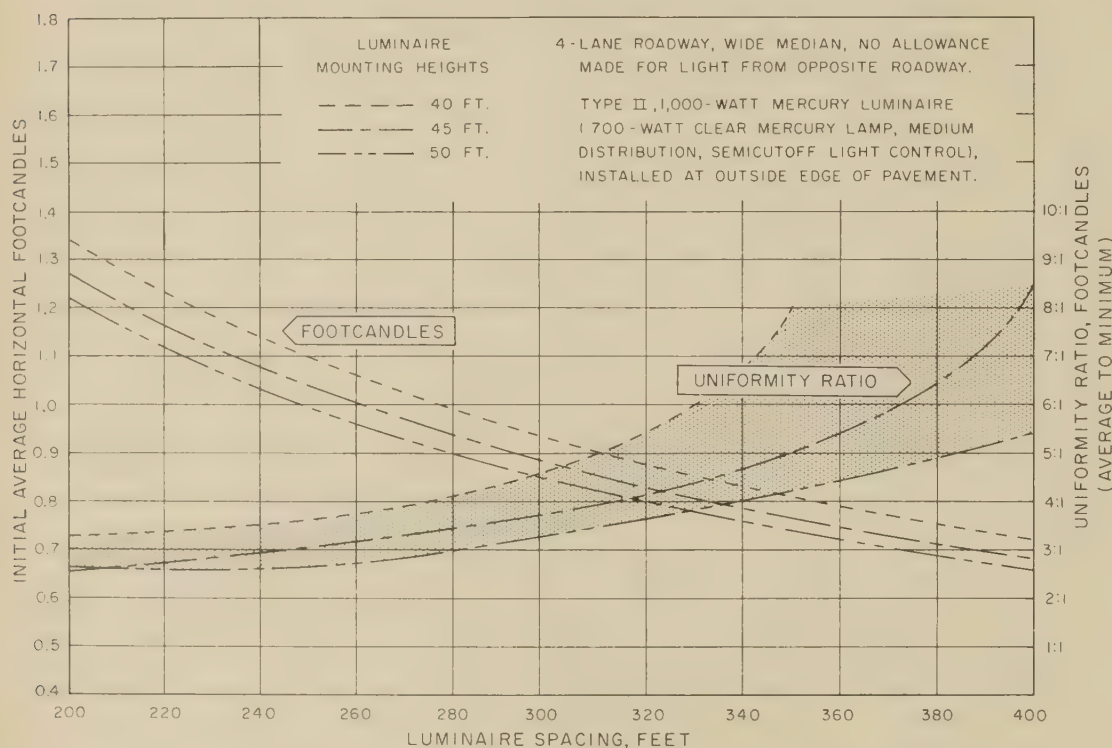


Figure 7.—Initial average footcandles and lighting uniformity ratio for different mounting heights and luminaire spacing for 4-lane roadway.

to 1. To obtain the same level of illumination, the uniformity ratio varies from 2.7 to 1 to 1.4 to 1 for a 45-foot mounting height, and from 1.6 to 1 to 1.2 to 1 for a 50-foot mounting height.

An analysis of the design and cost data tables shows that a 45-foot mounting height would be the most economical lighting design for a 2-lane roadway. The 45-foot mounting height also would be better than a 30-foot mounting height in relation to safety and esthetics. But a 50-foot mounting height would provide the most effective lighting, the best uniformity in illumination, and the least glare. The 30-foot mounting height would provide the most initial average horizontal footcandles.

Analysis of data for a 3-lane roadway, given in table 4, shows that a mounting height of 40

feet would be the most economical design. A 45-foot mounting height would provide the most effective lighting. At a mounting height of 50 feet, glare would be least; also, the 50-foot mounting height design would provide the best highway lighting system in relation to safety and esthetics. On the basis of the cost-effectiveness evaluation, the use of either a 45- or 50-foot design mounting height would be favored. On a 4-lane roadway, as shown in table 5, the 50-foot mounting height design would be a better lighting system on the basis of economy, uniformity, effectiveness, glare, safety, and esthetics. The 40-foot mounting height design would produce the most initial footcandles of illumination.

Bridge rail lighting, continuous rows of low mounted fluorescent luminaires placed adjacent to or in lieu of a bridge railing, eliminates

Table 7.—Interest factors used in computations of designs for highway systems

6-percent compound interest factors ¹		
Years	Single payment present worth	Uniform series capital recovery
1.....	0.9434	1.06000
2.....	0.8900	0.54544
3.....	0.8396	0.37411
4.....	0.7921	0.28859
5.....	0.7473	0.23740
6.....	0.7050	0.20336
7.....	0.6651	0.17914
8.....	0.6274	0.16104
9.....	0.5919	0.14702
10.....	0.5584	0.13587
11.....	0.5268	0.12679
12.....	0.4970	0.11928
13.....	0.4688	0.11296
14.....	0.4423	0.10758
15.....	0.4173	0.10296
16.....	0.3936	0.09895
17.....	0.3714	0.09544
18.....	0.3503	0.09236
19.....	0.3305	0.08962
20.....	0.3118	0.08718

¹ The 6-percent compound interest factors for single payment present worth and uniform series capital recovery calculations were based on investments made at the end of each year (maintenance, replacement, and operation) were assumed to be charges paid at the end of each year. Zero time ($n=0$) was assumed to be the day the installation was completed and operational.

the need for lighting poles and overhead luminaires. This type of lighting should be restricted to locations where overhead lighting cannot be used. The total annual cost for such an installation is approximately 10 times that of conventional overhead systems. Present brightness requirements may be met on 2-lane roadways at the 3½-foot mounting height, but whether these requirements are met on 3- and 4-lane roadways is questionable. Although a rail lighting system contributes to the esthetic appearance of a bridge and helps delineate the roadway at night, the problems inherent in maintaining a low mounted fluorescent system, coupled with the increase in annual cost, generally should rule out consideration of such a design. Exposure of luminaires to dirt from frequent splash of moisture on the highway makes it impracticable to maintain the same degree of cleanliness for luminaires mounted at 3½ feet as for overhead lighting. Use of bridge rail lighting designs should be reserved for special situations.

The estimated initial cost for a lighting system using 6-foot fluorescent luminaires is \$220,200 per mile of highway when 122 luminaires, mounted at 3½ feet, are installed in two rows. The equivalent annual capital cost per mile would be \$19,197; equivalent annual maintenance would be \$7,995; and annual power cost would be \$4,290.

Flexibility in choice of equipment and design of highway lighting systems seem to increase in relation to the mounting height of the systems. Recent lamp developments could encourage the use of towerlighting or floodlighting in the future. Interchange floodlighting has been used in Europe, but no installations have been made in this country.

(continued on p. 150)

Severance Case Studies— Bridging the Gap Between Findings and Their Application

BY THE OFFICE OF
RESEARCH AND DEVELOPMENT
BUREAU OF PUBLIC ROADS

Reported by¹ FLOYD I. THIEL, Economist,
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Introduction

THE GAP between the availability and application of findings from severance studies—land economic studies—for acquisition of land for highway right-of-way is of concern to all highway officials. Information on the type of findings available from severance studies and suggestions as to how these findings may be of use to appraisers and others concerned with highway construction are discussed in this article. Two sources of information are analyzed: the Bureau of Public Roads bank of severance studies, which is a central file of information; and reports on 2,262 remainder sales listed in *Narrative Reports of Highway Severance Effects: Index and Summary Analysis* (hereafter referred to as the Index), distributed to Public Roads and State highway department personnel.

The gap between findings and their application has occurred primarily because appraisers and others involved in right-of-way takings sometimes do not have access to the pertinent information when they need it. Although information has been collected on approximately 5,000 sales of highway severed property, difficulties seem to arise in getting the right information to the right place at the right time.

Beginning in 1961, the Bureau of Public Roads began collecting information on the effect of taking part of a property for highway right-of-way in a severance effects bank, which now includes 3,000 cases covering 4,000 sales of remainders from these cases. In addition, narrative reports have been collected on more than 2,262 remainder sales. Approximately 40 percent of the severance cases covered by the narrative reports are now recorded in the Public Roads severance bank maintained on electronic data processing equipment. The findings from these studies were intended to be the information that would be used to determine the present and future monetary effects of partial takings of property for right-of-way. These narrative reports have been useful for other purposes such as public relations and land use planning.

Amounts being received by owners of land taken for highway right-of-way construction for the National System of Interstate and Defense Highways and other Federal-aid highways, as payments for land taken, damages, and sales, often total more than had been anticipated, according to findings from studies of severance effects. Receipts often have totaled more than the estimated values, and losses have been relatively few and small.

The disparities in the estimated values and the actual values shown by analyses of findings—from the case studies in the Public Roads severance effects bank and 2,262 narrative reports on remainder sales—emphasize the savings that can be made. The findings also indicate that underpayments to landowners sometimes are being made.

The importance of applying the available findings from previous case studies to new acquisitions is stressed in this article. Attention is called to the possible source(s) of information, especially for current acquisitions that involve takings for unusual types of properties such as churches, golf courses, and/or schools. By applying these findings, highway takings can be evaluated more closely so that right-of-way can be acquired economically and owners can be paid equably.

Findings from the Public Roads severance bank of cases have been evaluated according to the benefits or losses to landowners, and findings from 2,262 remainder sales have been analyzed on an aggregate basis for different situations. Some of the facets of the analyses pertained to the relation of estimated values of remainder sales to usage before and after severance, and whether the remainder was landlocked or located near an interchange.

Although gaps exist between findings and application of the findings, some success has been achieved in using information from these studies. For example, landlocked areas had commonly been estimated to be damaged 90 percent by severance. But severance studies have shown that such damages usually amount to only about 10 percent of the original value of the land; this finding is now being applied to right-of-way settlements. Thus, some savings in acquisition costs of right-of-way have been accomplished by more accurate estimates of the value of landlocked parcels, as shown in figure 1.

The case study approach is basic for an understanding of the effects of right-of-way acquisition and for providing information in a form that can be applied to future land acquisition appraisals. As the States have completed more studies, the size of the task of recording and filing the data so that the information can be obtained readily has become larger. To ease this task, some States and Public Roads are relying on electronic data processing equipment. When a computer is used to record data, case information can be sorted and analyzed more readily and findings on comparable case situations can be provided more quickly and easily.

Public Roads has had limited success in using the computer to locate information on

comparable studies. Some requests, however, have been filled for comparable cases that could be used in current land acquisition situations. Sometimes searches of the bank have been unsuccessful because time required for programs having higher work priorities prevented an adequate search. Also, the Public Roads severance bank contains only a few of the unusual types of cases.

Obtaining findings for the severance bank on takings from properties used for special purposes is very desirable; such information would increase the effectiveness of the data bank. Some of these special purpose property uses are for roller coasters, golf courses, riding stables, schools, and churches. To make it easier to enter data in the severance bank on cases pertaining to special use properties, a shortened case study form has been developed by Public Roads; this form is compatible to the longer form now being used and to the computer programs that have been developed.

Conclusions

Bridging the gap between findings from land economic studies and the application of the findings depend primarily on organization of the findings and making them available in usable form. Case studies for comparable situations can ordinarily be obtained from

¹ Presented to the Land Economic Study Conference at the 24th annual National Seminar of American Right-of-Way Association, Denver, Colo., June 7, 1966.

² Ruth B. Ross, Gwen Van Domelen, John Yasnowsky, Jr., and M. Donald Nolden, also contributed work on which this article was based.

State highway departments; the Bureau of Public Roads can often help locate information for unusual types of cases by use of its severance effects bank maintained on EDP or by use of the Index. Sometimes the findings from land economic studies need to be aggregated and analyzed collectively. The conclusions listed in the following statements have been based on an aggregated analysis of cases in the Public Roads severance effects bank and narrative reports.

- Land values have increased from the estimated value for about four cases out of five.

- Special characteristics have been associated with the remainders for which sales prices were more than the average estimated value. Some of these characteristics of the remainder parcel are: (1) nearness of the remainder to an interchange area; (2) remainders caused by Interstate highway takings; and (3) use of the remainder for commercial purposes.

- Owners of landlocked remainders are not damaged to the extent anticipated at the time of settlement.

- Owners of vacant property are more likely to gain more from the sale of remainders than owners of residential or agricultural properties.

Narrative Reports

In addition to the nearly 4,000 sales (more than 3,000 cases) recorded in the Public Roads severance bank, approximately 2,900 narrative case studies for 2,262 remainder sales have been processed. These narrative reports have been listed and compared in *Narrative Reports of Highway Severance Effects: Index and Summary*. This Index should make it easier for an appraiser to obtain information about a comparable situation from printed studies. The appraiser can check the Index to determine whether a narrative report is available for a situation similar to his current assignment. If so, he may obtain a copy of the report from his State highway department library, the State highway department originating the study, or from the Bureau of Public Roads.

The appraiser can refer to the Index to determine whether a severance study has been made on a landlocked parcel near an interchange for which the value has been within a specified range. Or, an appraiser having an assignment concerning leaseholds would learn from the Index that severance studies involving leaseholds have been reported by Florida, Colorado, Georgia, and Illinois. Narrative reports involving severance studies for church and school properties have been made by Michigan, Texas, Nebraska, California, Florida, Kentucky, Illinois, Ohio, and others. Some other special severance studies listed in the Index include land used for a boys home, a hunting camp, a drive-in theater, a trailer park, a golf course, a zoo, a gun target range, and a dam project, a remainder selling for corporate stock, a sale of more than a million dollars, and a remainder that had a loss of a lake view.

This Index will not end the need for the Public Roads severance bank of cases as approximately half the cases in the bank have not been reported in narrative form. But the Index should make information more readily available on the 2,900 severance cases covered in narrative reports. Such information should help bridge the gap between severance effects studies and the application of the study findings.

Overall Analysis Needed

Shortening the gap between study findings and application to similar situations might also be accomplished by analyzing severance studies and making the results general available. The need for such an analysis was stated by Rudolf Hess, of the California Division of Highways, before the American Institute of Real Estate Appraisers, meeting

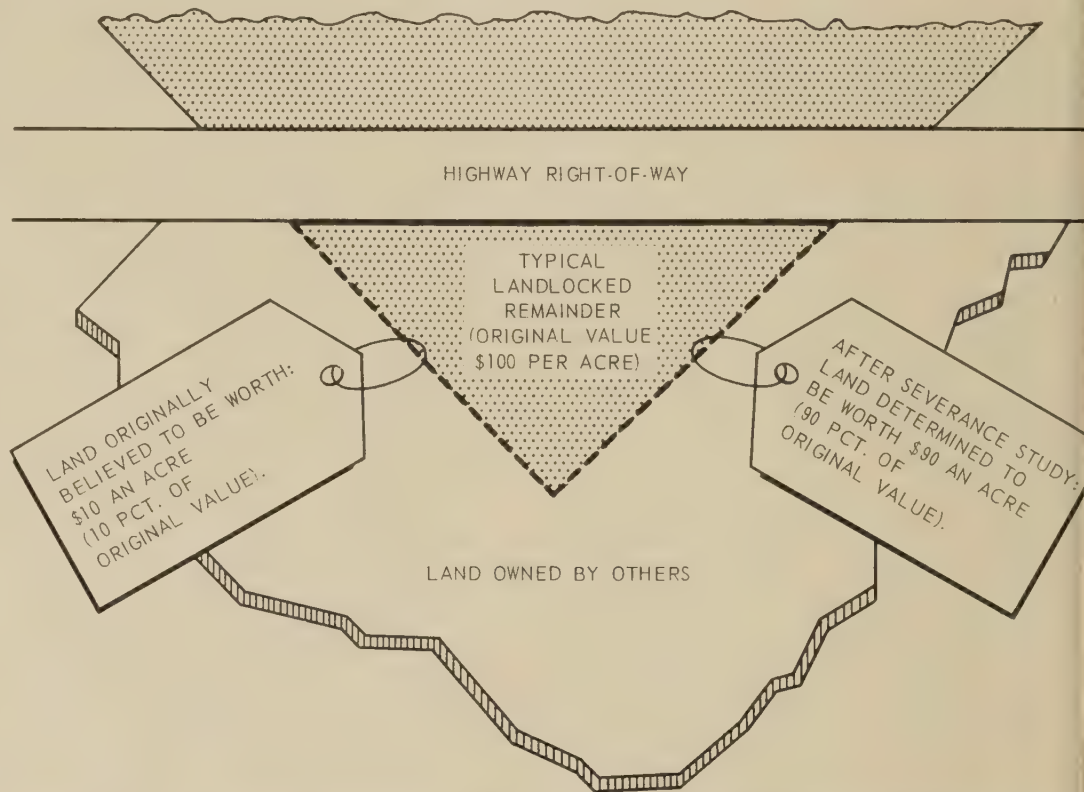


Figure 1.—Savings possible from use of findings from studies on severance effects

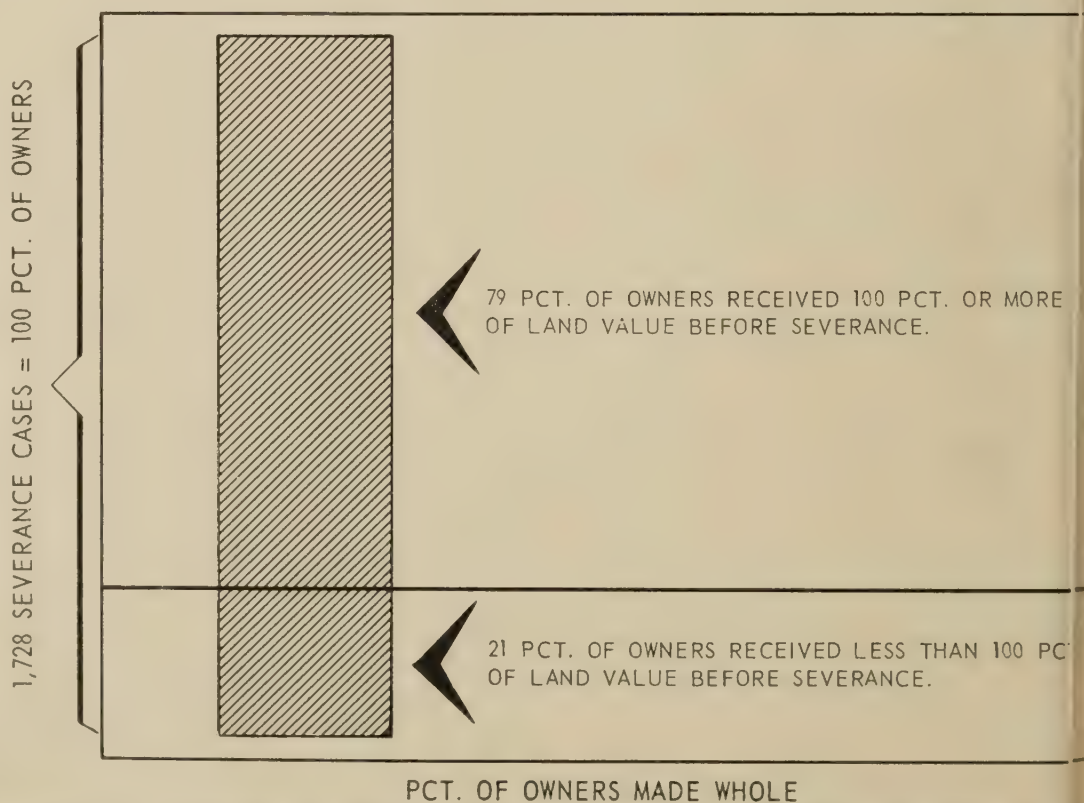


Figure 2.—Percentage of owners made whole and percentage who lost based on 1,728 severance effects cases.

Los Angeles in November 1964, as "The remainder parcel sales data collection is one of the first direct research links between the appraisal profession and land economics. The analysis of remainder parcel sales data may provide the vehicle for a firmer marriage of these two specialized areas; it may provide a means for appraisers to more conveniently and confidently consider land economic data and theory. Collective analysis is the key.

Collective analysis is a tool of land economics. . . . Several States have used overall analyses of severance studies. For example, A. B. Grace of the Texas Highway Department in an article, *Severance Damage Studies*, Right-of-Way, vol. 13, No. 1, February 1966, pp. 55-60, presented general findings on the Texas experience with severance studies. Mr. Grace believes that severance effects studies should

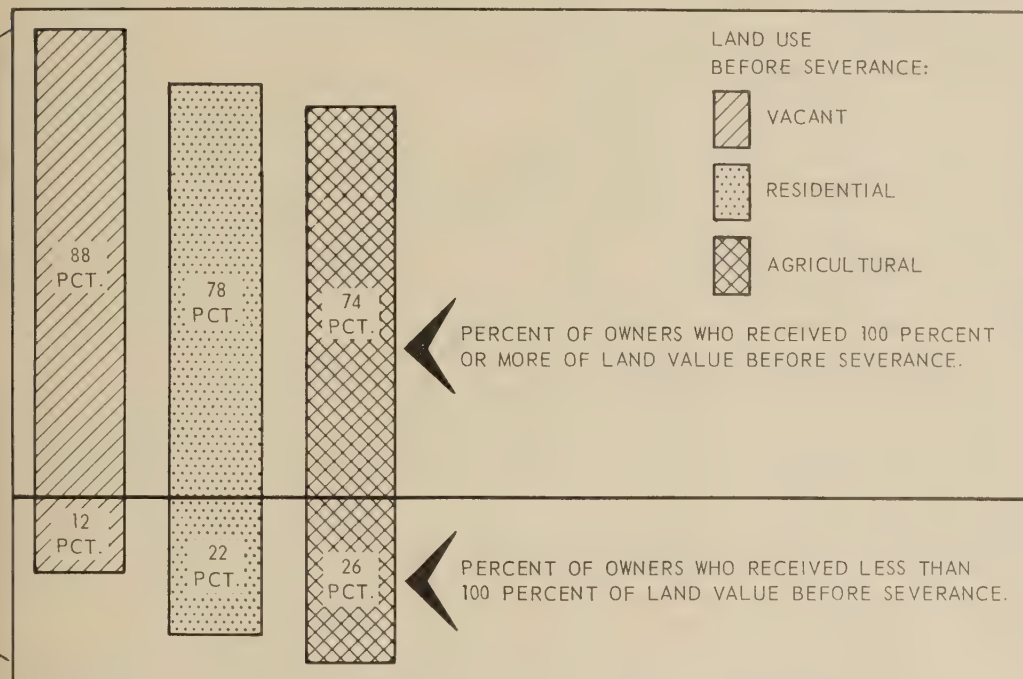
not be used to " . . . advocate the development of appraisal formulas . . . " but " . . . as a source in locating comparable sales and as general information in predicting the change in use of a particular remainder." Some analytical work has been done by Public Roads on both the 4,000 sales recorded in its severance bank of cases and the 2,262 sales for which the States have issued narrative reports. A few of the more important findings from these analyses are described here.

Findings from the Public Roads bank of severance studies and the narrative reports are very similar, as might be expected when the same case is reported in the bank and the narrative report. Approximately 60 percent of the narrative reports are for severance cases in the bank and nearly 40 percent of the cases in the bank are also reported in narrative form. The agreement of the findings from the two sources is shown by approximately the same percentage of owners (about 80 percent) receiving more than 100 percent of the original value of their land. Better than average agreement is also present in the findings concerning remainders near interchanges, remainders used for commercial purposes, and takings for Interstate highway routes.

Severance Bank Findings

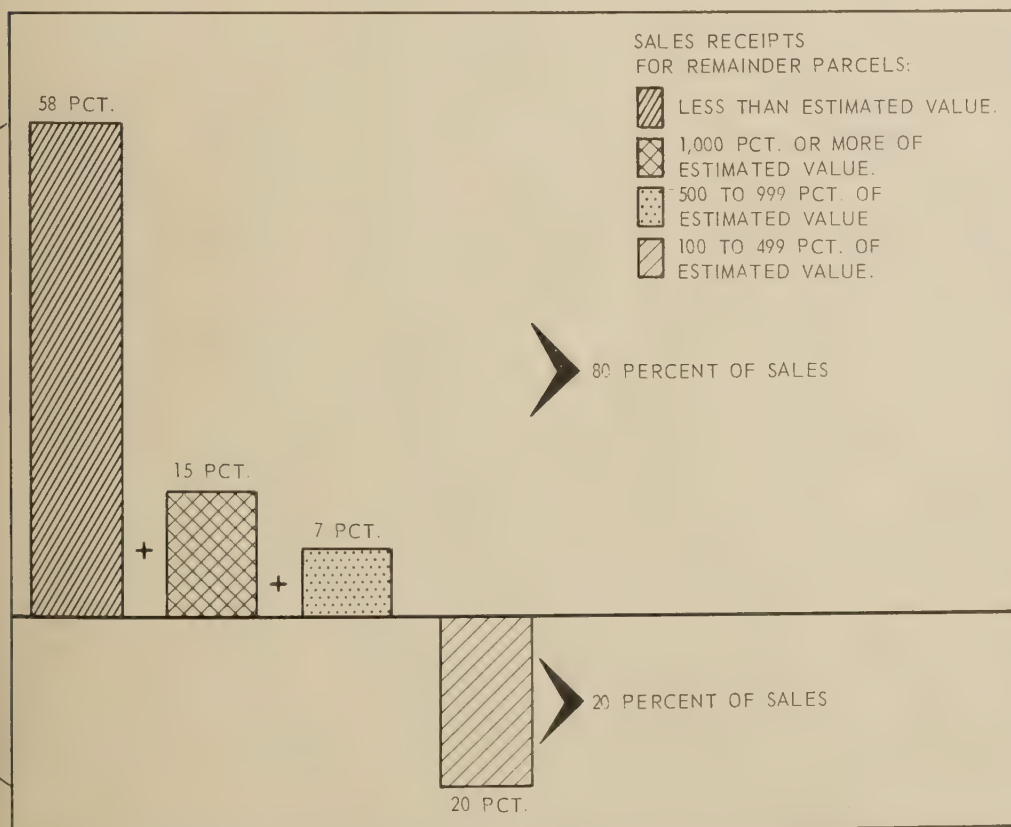
Many remainder parcel sales involve only a part of the remainder after a taking for highway right-of-way. When any part of the remainder has been sold, a preliminary comparison of the per acre value of the parcel sold can be made with the per acre value of the entire property at the time of severance. Such a comparison obviously cannot be conclusive; but its use makes possible a per acre comparison of the value of the part of the remainder that has been sold to the value of the entire property. The parcels that have been sold may have been more or less desirable than the entire property or the entire remainder. Such a comparison shows what happened to land values rather than to owners and does not show whether owners were benefited or damaged. However, such a comparison permits some tentative findings about highway severance effects in many situations where only part of the entire remainder has been sold. Thus a recovery rate can be determined by dividing the value per acre or per square foot of part or all of the remainder that has been sold by the per acre value at the time of the highway taking. Thus a recovery rate of more than 100 percent means that the remainder has had an increase in unit value. Conversely, when the rate is less than 100 percent, the remainder has declined in value. A recovery rate of more than 100 percent for remainder sales has been shown in most severance studies. Less than one-fourth of the remainder sales in the Public Roads bank had a recovery rate of less than 100 percent. About one-fifth had recovery rates of 500 percent or more and one-tenth had recovery rates of 1,000 percent or more.

Because of the extremely large increases in per acre values for some remainder parcels, simple arithmetic averages may not be a



PCT. OF OWNERS MADE WHOLE, BY LAND USE BEFORE SEVERANCE

Figure 3.—Land use before severance, by percentage of owners made whole, based on 1,728 severance effects cases.



REMAINDER SALES RELATED TO ESTIMATED VALUES OF PARCELS

Figure 4.—Remainder sales and estimated values, based on 2,262 narrative reports on severance studies.

satisfactory summary measure of the typical recovery rate for severed land parcels. Median values provide another way of summarizing the overall recovery rate. As a median is a middle value with half of the cases above and half of them below, those remainder parcels having extremely large recovery rates do not have such a noticeable effect on median values as they do on average values. Thus, for the nearly 4,000 sales in the Public Roads severance bank of cases, the median recovery rate is 160 percent and the average value is 495 percent.

When sales of remainders are made after a lapse of time (1 year or more) after the taking, allowance should be made for general land value changes in the area. For this adjustment, an average increase in value of 7 percent per year was used for data reported here. Where this adjustment was applied, the overall median recovery rate was approximately 140 percent. For sales that are made 2, 3, or more years after the taking, recovery rates are larger than the overall recovery rate, even after the adjustment has been made for general land value increases. For example, the adjusted recovery rate for remainder parcels sold more than 3 years after the taking was nearly 170 percent. Apparently the value of remainders tends to go up more than land values generally, at least for 3 or more years following the right-of-way taking.

Comparison of the recovery rates for different types of remainders—for example, landlocked remainders—shows some significant variations. Damages to landlocked remainders previously have been estimated at 90 percent or sometimes at 100 percent. An estimate that the value of a remainder parcel will be damaged 90 percent means that the estimated recovery rate is only 10 percent. On the basis of cases in the Public Roads severance bank, such an estimate is seldom realistic. Data on the 94 landlocked cases in the bank suggest that landlocked parcels are damaged about 8 percent and that the median recovery rate for landlocked parcels is 92 percent. Landlocked remainders, however, are damaged more than other types of remainders. All types of remainders in the severance effects bank had a median recovery rate of 160 percent and an average recovery rate of 495 percent. Also more landlocked remainders are damaged—have a smaller recovery rate—than other remainders. About half of the landlocked remainders had recovery rates of less than 100 percent but only about one-fourth of the other remainders had recovery rates of less than 100 percent.

Special analysis has been made of changes in value of remainder parcels near interchanges, especially interchanges on the Interstate system. About 30 percent of the remainder cases in the Public Roads bank are located within a half mile of an interchange, a distance often used to distinguish between areas called interchange areas and noninterchange areas. As might be expected, recovery rates for remainders located within

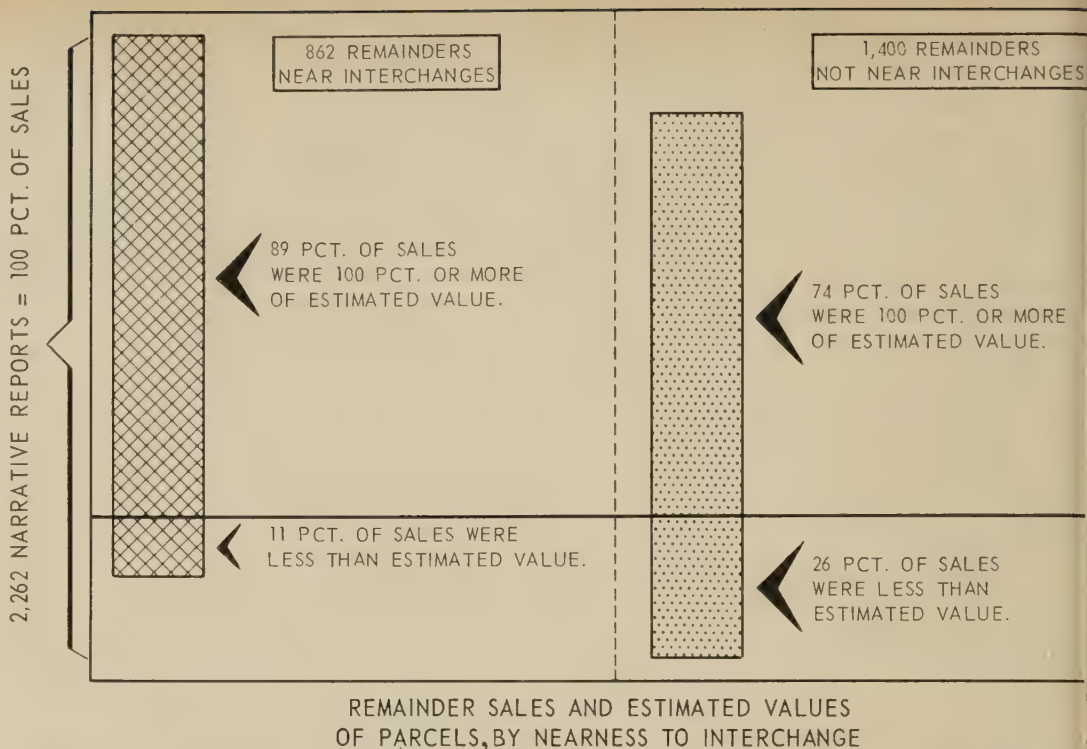


Figure 5.—Remainder sales and estimated values by nearness of remainder to an interchange area, based on 2,262 narrative reports on severance studies.

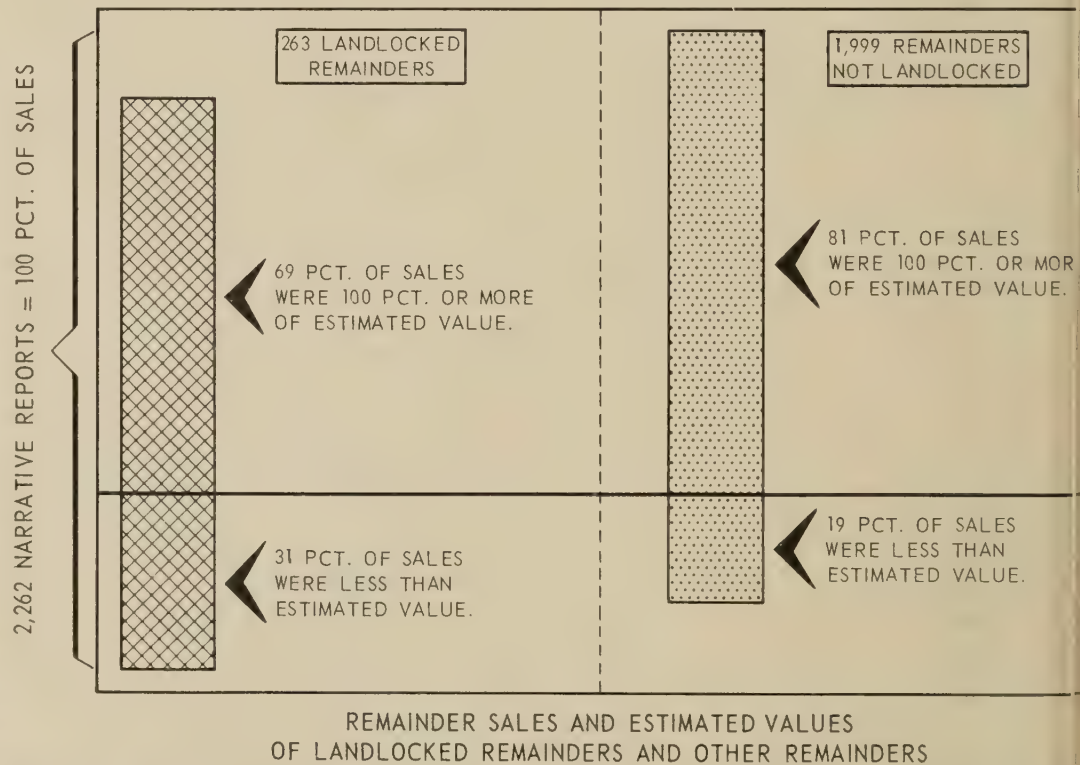


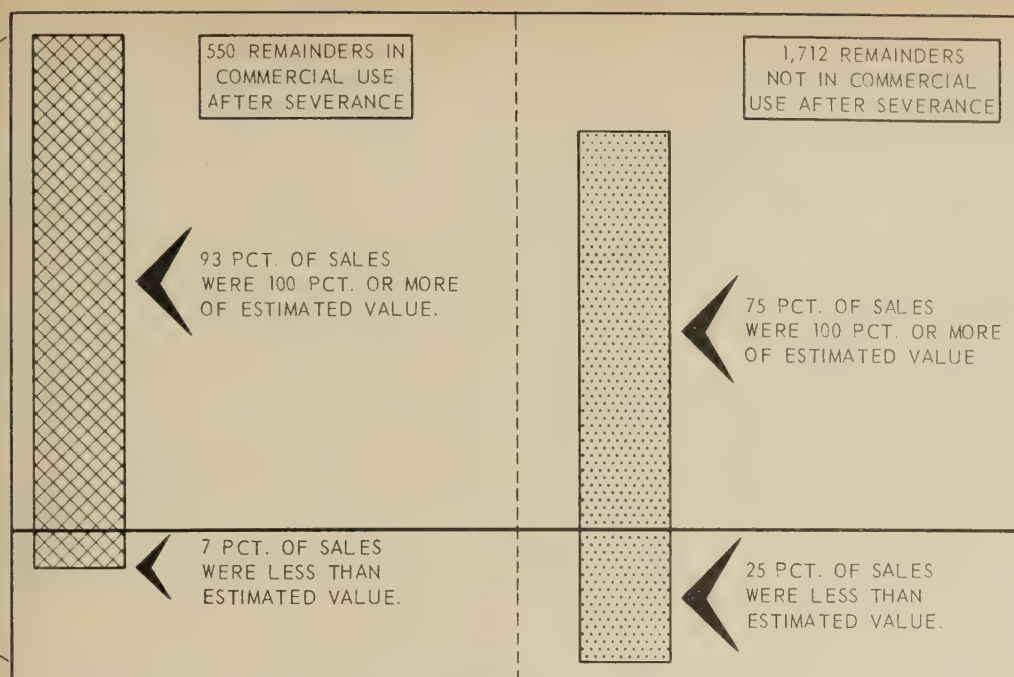
Figure 6.—Effect of remainder being landlocked by remainder sales and estimated values based on 2,262 narrative reports on severance studies.

a half mile of the interchange area are better than the recovery rates for comparable remainders located farther away.

Owners Made Whole

The entire remainder parcel has been sold for more than 50 percent of the cases in the Public Roads severance bank. From these cases, enough facts are available for a determination as to whether the owner is in as good a position as he was before the taking for right-of-way acquisition. To make this determination information is needed on (1) value of the property before right-of-way

acquisition, (2) payment to the owner of the part taken for the highway and estimated damages to the remainder, and (3) receipts for the entire remainder. When the receipts, for the right-of-way taken plus the amount received for sale of the remainder amount to as much as the estimated property value before the taking, the owner can be said to have been made whole. For the 1,728 cases in the Public Roads bank in which the entire remainder has been sold, approximately 4 out of 5 property owners were made whole. The other property owners had less money after sale of the entire



REMAINDER SALES AND ESTIMATED VALUES OF PARCELS,
BY COMMERCIAL AND NONCOMMERCIAL LAND USE AFTER SEVERANCE

Effect of land use

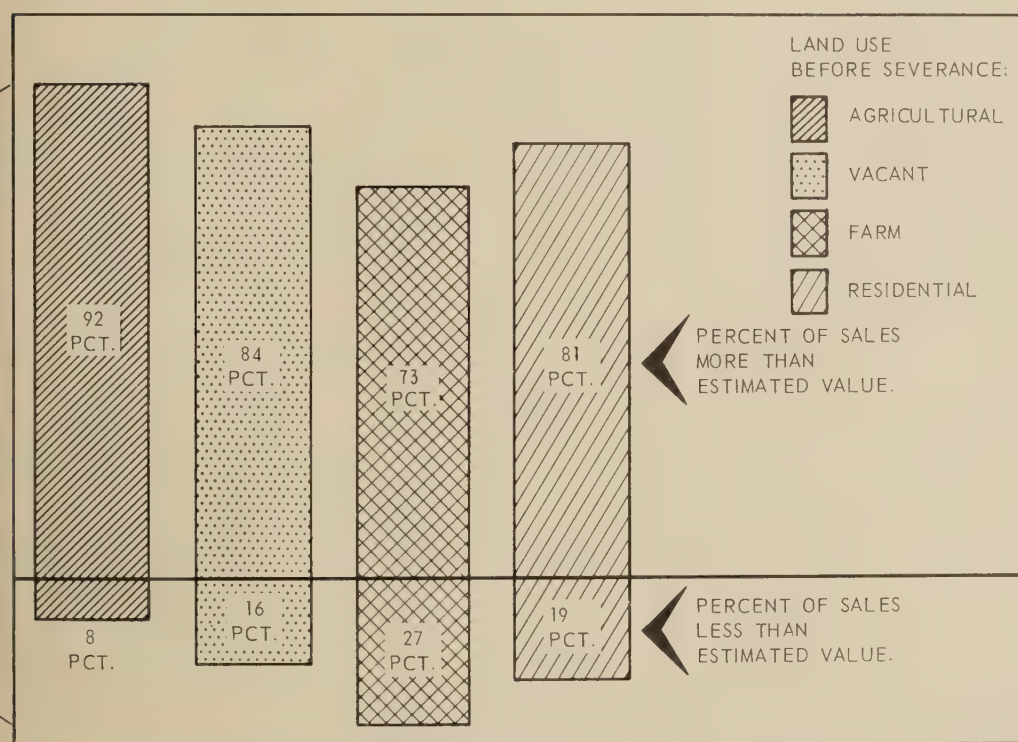
Use of the property before severance, whether vacant, residential, or agricultural, affected the receipts of the owners for cases in the Public Roads bank. Owners of vacant land had receipts amounting to 135 percent of the before value of their property. Owners of residential and agricultural properties had receipts equaling 110 percent and 116 percent of the before value of their property. Owners of vacant property generally fared better than owners of residential or agricultural property. A partial explanation of the value increases of vacant land is that it is more frequently put to a more profitable after use than is residential and agricultural property.

As more experience has been gained in relation to right-of-way acquisition, the potential value of vacant property has been recognized. Data now available from the bank show that a smaller percentage of owners of vacant property—49 percent—are being paid damages than owners of agricultural and residential property—67 percent each. Latest available information on percentages of owners paid damages and the percentage having apparent losses, by land use before the highway taking are, respectively: (1) vacant, 49 percent and 12 percent; (2) agricultural, 67 percent and 26 percent; and (3) residential, 67 percent and 22 percent. Data combined for these three uses of land before the highway taking show that 61 percent of the owners were paid damages and 20 percent apparently had losses. The relation of receipts to estimated damages for these land uses before the taking is shown in figure 3.

Narrative Reports

When a group of narrative reports has been assembled, analyses of the findings can be made and general comparisons noted as to which types of remainder parcels have been sold for a gain or a loss. Only a general indication of gains or losses can be obtained from aggregating narrative reports. State laws or practices differ as to the bases used for determining damage payments, the different uses of control areas, and the different methods for adjusting estimates in relation to general changes in land use. The information taken from the narrative reports permits a comparison of estimated values of remainder parcels and sales prices. Thus an indication can be obtained of the experience that owners have in relation to the sales of remainders. Generally, owners of remainder parcels that were sold for more than the estimated value can be said to have benefited. By the same reasoning, when the remainder was sold for less than its estimated value, the loss can be equated generally with a loss by the landowner.

Four-fifths of the sales reported in the 2,262 narrative cases exceeded the estimated values of the parcels sold. Also, for more than half of the narrative cases reported, sales prices exceeded the estimated values of the remainders by 50 percent or more. Large gains of 500 percent or more of the estimated value were noted for 15 percent of all narrative sales. Conversely, 20 percent of the remainder



REMAINDER SALES AND ESTIMATED VALUES OF PARCELS,
BY USE OF LAND BEFORE SEVERANCE

Figure 8.—Effect of land use before severance on remainder sales and estimated values, based on 2,262 narrative reports on severance studies.

remainders than the value of their property at the time of severance, as shown in figure 2. Some owners received total receipts amounting to several times the worth of their property before the taking for the highway.

An analysis of the bank case data on owners made whole—those who had receipts more than the original value of their property—shows that most of the losses were moderate. For nearly half of the owners who lost money, the loss was not more than 10 percent of the

original value of the property. In 5 percent of the cases where the landowners had losses (1 percent of all sales recorded in the bank) the amount received was less than 50 percent of the original value. Efforts to close the gap between findings from severance studies and application of the findings should help prevent inadequate payments for right-of-way; this is a problem of as much concern to conscientious highway builders as excessive payments.

sales reported in the narrative cases were for less than the estimated value of the remainder. The relation between estimated values and remainder sales is shown in figure 4.

Nearly 900 cases for which there are narrative reports were for remainder sales for land near interchange areas. Nearly 90 percent of the remainder sales for parcels located near an interchange exceeded the estimated value of the remainder. But only about 75 percent of the remainder sales for parcels located away from an interchange area exceeded the estimated value. Also, larger gains in sales of 500 or 1,000 percent of the estimated value were more pronounced for interchange areas. This is shown in figure 5. These differences in relation to nearness to an interchange are significant at the 95 percent level of confidence.

Because of problems related to appraising the value of landlocked remainders when right-of-way for a controlled-access highway is

acquired, special attention has been given to reports for this type of remainder. More than a tenth of the sales—262 of the 2,262 cases reported in narrative form—are landlocked remainder parcels. Sales for nearly a third of these remainders were less than the estimated values. At the same time, sales prices greatly exceeding estimated values are received more often for landlocked remainders than for other remainders. These findings—gains and losses for landlocked remainders in excess of those for other remainders—emphasize the problems associated with appraising landlocked remainders. The relation of sales and estimated values for remainders landlocked and those not landlocked is shown in figure 6.

Experience and logic indicate that land use and land value are positively related. Thus, if the ultimate use of a remainder can be determined at the time of the highway taking, this information can be useful in estimating

the value of the remainder. For example, remainder parcels that are used for commercial purposes after the severance seem to increase in value more than remainders used for other purposes. This is substantiated by the case that of 550 remainders in commercial use after the taking, 12 percent sold for 100 percent or more of the estimated value. Also, only 7 percent of the remainders used for commercial purposes sold for less than the estimated value, but 25 percent of the properties not used for commercial purposes sold for less than the estimated value. These relations are shown in figure 7. The use of the property at the time of the highway right-of-way acquisition also is an indicator of the possible value of the remainder. Vacant land or land in commercial use is more likely to increase in value than land in residential or farm use. More data on such situations are shown in figure 8.

Application of Statistical Concepts to Accident Data

(continued from p. 137)

Office of Technical Services PB 151055, June 1958.

(2) *Application of Statistical Quality-Control Techniques to Analysis of Highway-Accident Data*, by Monroe L. Norden, Jesse Orlansky, and Herbert H. Jacobs, IIRB Bulletin 117, Statistical Analysis of Highway Accidents, 1956, pp. 17-31.

(3) *Operational Route Analysis*, by Burton M. Rudy, HRB Bulletin 341, Accident Analysis and Speed Characteristics, 1962, pp. 1-17.

(4) *Two Simple Techniques for Determining the Significance of Accident-Reducing Measures*, by Richard M. Michaels, PUBLIC ROADS, A JOURNAL OF HIGHWAY RESEARCH, vol. 30, No. 10, October 1959, pp. 238-239.

(5) *Daylight "Lights-On" Plan by Police*, New York Authority, by Edmund Carlin, Traffic Engineering, vol. 36, No. 3, December 1965, p. 17.

(6) *Technical Notes, the Effectiveness of Painted Channelization*, by Ronald W. Failmezger, Traffic Engineering, vol. 36, No. 5, February 1966, pp. 47-49.

Economic Study of Luminaire Mounting Heights

(continued from p. 144)

Actual installation of floodlighting systems would be necessary before the system could be fully evaluated as to effectiveness and economy. But, interchange floodlighting costs, shown in table 7, seem to be about equal to the costs of a conventional, 30-foot mounting height design. Also safety and esthetic considerations favor floodlighting because fewer poles are needed in this design. However, studies to determine the pavement brightness, glare, and effectiveness in fog or on wet pavement are needed to evaluate floodlighting or tower-lighting. Governing conditions, such as the type of property development adjacent to the highway, the highway geometrics, and the personal choice of the decision-maker, influence the cost-effectiveness evaluation of a specific lighting installation. Additional information regarding the differences in design criteria and field measurements would affect the final decision.

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The illustrated publication points out the concern of the Bureau of Public Roads and the State highway departments for the total impact of highways on all the elements of life. A broad picture is presented of the many social values, such as highway safety and beautification, involved in the National System of Interstate and Defense Highways and other Federal-aid highway programs.

The 1966 annual report also reviews the progress of the Bureau of Public Roads in

conservation and recreation and describes the highway construction in national forests, parks, and on other Federal lands that is done under the direct supervision of Public Roads. Foreign activities including construction, financing, and technical assistance are also outlined.

The revitalized interest in the human values associated with highway progress is illustrated by the change in size and presentation of the 1966 annual report; *Highways and Human Values* has been designed in both copy and format to be of more interest to the general public. Many photographs illustrate the extensive work being done by the Bureau of Public Roads to satisfy the needs of transportation as well as society. Statistical tables that cover the progress and status of the Federal-aid and allied highway programs for fiscal year 1966 are published in a supplement. The *Supplement to Highways and Human Values*, also can be purchased from the Superintendent of Documents; it is priced at 25 cents, prepaid.

Presplitting, A Controlled Blasting Technique for Rock Cuts

Presplitting, A Controlled Blasting Technique for Rock Cuts is a 36-page research and development report presenting a state-of-the-art summary of a relatively new controlled blasting technique that will be of interest to State highway engineers, contractors, manufacturers, consultants, university engineering personnel, and others engaged in rock excavation activities. The report is available from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402, for 30 cents a copy, prepaid.

The findings of a staff study by the Bureau of Public Roads on rock presplitting are presented, particularly as they apply to highway construction. The different field practices used to improve rock blasting operations are reviewed, and the use of presplitting is emphasized as a method of producing smooth wall surfaces that require less maintenance and provide more safety during highway construction.

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